Columbia River Project Water Use Plan

Kinbasket Fish and Wildlife Information Management Plan

Kinbasket and Revelstoke Reservoirs Ecological Productivity Monitoring

Implementation Year 8

Reference: CLBMON-3 and CLBMON-56

Kinbasket and Revelstoke Reservoirs Ecological Productivity Monitoring –*Year 8 and Year 4 (2015)*

Study Period: 2015

K.E. Bray
BC Hydro

January 2017

Kinbasket and Revelstoke Reservoirs Ecological Productivity Monitoring
Year 8 (2015) Progress Report

Morning mist rising over Mica Dam, July 2015

Prepared by:
Karen Bray
Revelstoke, B.C.

This is a progress report for a long term monitoring program and, as such, contains preliminary data. Conclusions are subject to change and any use or citation of this report or the information herein should note this status.

Suggested Citation for Progress Report:

Bray, K. 2017. Kinbasket and Revelstoke Reservoirs Ecological Productivity Monitoring. Progress Report Year 8 (2015). BC Hydro, Environment. Study No. CLBMON-3 and CLBMON-56.

Suggested citation for individual reports contained within:

Brandt, D. 2017. Phytoplankton populations in Kinbasket and Revelstoke Reservoirs, Upper Columbia Basin, British Columbia - 2015. Prepared for BC Hydro, Water Licence Requirements. 40 pp. + apps. Appendix 5 *in* Bray, K.E. 2017. Kinbasket and Revelstoke Reservoirs Ecological Productivity Monitoring. Progress Report Year 8 (2015). BC Hydro, Environment. Study No. CLBMON-3 and CLBMON-56.

Acknowledgements

The successful implementation of such a large and complex project is due to the continuing efforts of many people and they are gratefully acknowledged for their valuable contributions and support.

Field Crew
Beth Manson, BC Hydro
Pierre Bourget, BC Hydro
Morgan Davies, Ministry of Environment
Allison Hebert, Ministry of Environment

Study Team
Dr. Roger Pieters, University of British Columbia
Tyler Weir, Ministry of Forests, Lands and Natural Resource Operations
Dale Sebastian, Ministry of Forests, Lands and Natural Resource Operations, Retired
Shannon Harris, Ministry of Environment

Specialised Analyses
Darren Brandt, Advanced Eco-Solutions
Dr. Lidija Vidmanic, Limno Lab

BC Hydro Personnel
Jim Van Denbrand, Fleet Services
James Crossman, Environment
Doug Johnson, Environment
Margo Sadler, Environment

Table of Contents

List of Figures and Tables

APPENDICES

1.0 Introduction

This report summarises the Year 8 (2015) implementation of CLBMON-3 Kinbasket and Revelstoke Reservoirs Ecological Productivity Monitoring project ("the study"). This report contains preliminary data and conclusions are subject to change. Any citations of this report or the data contained herein must note this status.

The Columbia River Water Use Plan (WUP) (BC Hydro 2007a) was concluded in 2004 following four years of public consultation (BC Hydro 2005). Water Use Plans were developed for each of BC Hydro's facilities to achieve optimal balance among operations and environmental and social values.

A lack of basic ecological data and information on Kinbasket and Revelstoke Reservoirs impeded informed decisions for any operational changes in the upper Columbia River system. The WUP Consultative Committee acknowledged the importance of understanding reservoir limnology and the influence of current operations on ecosystem processes for planning future water management activities. Therefore, a monitoring program was recommended to provide long-term data on reservoir limnology and the productivity of pelagic communities. This study is conducted in conjunction with CLBMON-2 Kinbasket and Revelstoke Reservoirs Kokanee Population Monitoring and is scheduled for implementation over twelve years (2008-2019).

As a result of the Environmental Assessment for the addition of two turbines at the Mica Generating Station (Units 5 and 6), the Terms of Reference for this study was amended to include a component for addressing the potential influence of the new units on reservoir productivity. This component, CLBMON-56, is an eight year study focussing on fine scale measurement of temperature in Kinbasket and Revelstoke Reservoirs to further refine data on circulation, and thus, production. The fourth year of this study was implemented in 2015 and annual results are included together with CLBMON-3 annual report (Appendix 8).

1.1 Management Questions

A Terms of Reference (TOR) (BC Hydro 2007b) for this study and revised in 2011 to include an addendum for Mica 5/6 (BC Hydro 2011b) outlines the rationale, approach, and primary management questions to be addressed. The TOR also provides a framework for implementation. The study is to focus on:

i) Reservoir trophic web mechanisms and dynamics;

ii) Obtaining measurements of aquatic productivity that can be used as parameters for system modeling; and

iii) Determining key indicators of change in pelagic production that would ultimately affect food availability and, thus, growth of kokanee.

The management questions to be addressed by this study are as follows:

i) What are the long-terms trends in nutrient availability and how are lower trophic levels affected by these trends?
ii) What are the interactions between nutrient availability, productivity at lower trophic levels and reservoir operations?
iii) Is pelagic productivity, as measured by primary production, changing significantly over the course of the monitoring period?
iv) If changes in pelagic productivity are detected, are the changes affecting kokanee populations?
v) Is there a link between reservoir operation and pelagic productivity? What are the best predictive tools for forecasting reservoir productivity?

vi) How do pelagic productivity trends in Kinbasket and Revelstoke reservoirs compare with similar large reservoir/lake systems (e.g., Arrow Lakes Reservoir, Kootenay Lake, Okanagan Lake, and Williston Reservoir)?

vii) Does the addition of Mica Units 5 and 6 influence pelagic productivity? (added in 2011)

viii) Are there operational changes that could be implemented to improve pelagic productivity in Kinbasket Reservoir?

1.2 Objectives

The study objectives are to conduct reservoir pelagic productivity monitoring and establish long term sampling sites and consistent methodologies and analyses for comparison with other Columbia reservoir monitoring programs (e.g. Arrow Lakes Reservoir, Kootenay Lake).

2.0 Study Implementation

The study team met on March 11, 2015, to discuss progress on the management questions, evaluate the sampling program to date, and set the 2015 (Year 8) work plan. The monitoring program is implemented in a phased approach in conjunction with the Kinbasket-Revelstoke Reservoirs Kokanee Population Monitoring program (CLBMON-2). Sampling is planned on a 4-year cycle and reviewed annually, thereby taking advantage of information gained in each sampling period to define the data needs for future years. Each phase will conclude with a synthesis report; an annual progress report is prepared in intervening years. The first phase synthesis report covering 2008-2011 has been completed (Bray et al. 2013); the next synthesis report will include data to 2015.

Implementation of this study continues to follow the approach of using a combination of in house and external resources. Overall project management and field work is conducted using in house BC Hydro resources and external expertise is secured to provide field sampling, analyses, and reporting for specific components

This eighth annual report presents a study overview followed by individual progress reports for the physical processes and biological components of the 2015 sampling year as per previous progress reports (Bray 2016a, 2016b, 2014, 2013, 2012; BC Hydro 2011a; BC Hydro 2010). Some chapters include annual progress reports for both 2014 and 2015 results that are repeated in the 2014 annual study report. Also included is the combined third and fourth annual reports for CLBMON-56 (Appendix 8). More specific information pertaining to individual year monitoring results is contained in these reports.

In Year 8 (2015) regular reservoir monthly sampling began in April and concluded in October at four stations in Kinbasket reservoir and three stations in Revelstoke reservoir (Figure 1). Sampling sessions on Kinbasket reservoir were conducted at reservoir elevations between 740.5 m and 750.8 m (Figure 2). Sampling protocols remained unchanged from the previous year (Table 1). Inclement weather and dangerous reservoir conditions precluded sampling of some Kinbasket stations in April (Columbia Reach) and October (all but Forebay).

Unusual operating conditions in 2015 are described in Appendix 1 (Hydrology). Due to drought conditions in the basin and a triggering of Columbia River Treaty obligations, discharge through Revelstoke reservoir was unusually high throughout the productive seasons. A significant rainfall event in late September resulted in highly turbid tributary inflows throughout the two reservoir basins. The lack of snow cover at high elevations from a very warm (strong El Nino) year resulted in sediment input into tributaries throughout entire watersheds.

Figure 1. Location of regular sampling stations on Kinbasket and Revelstoke reservoirs.

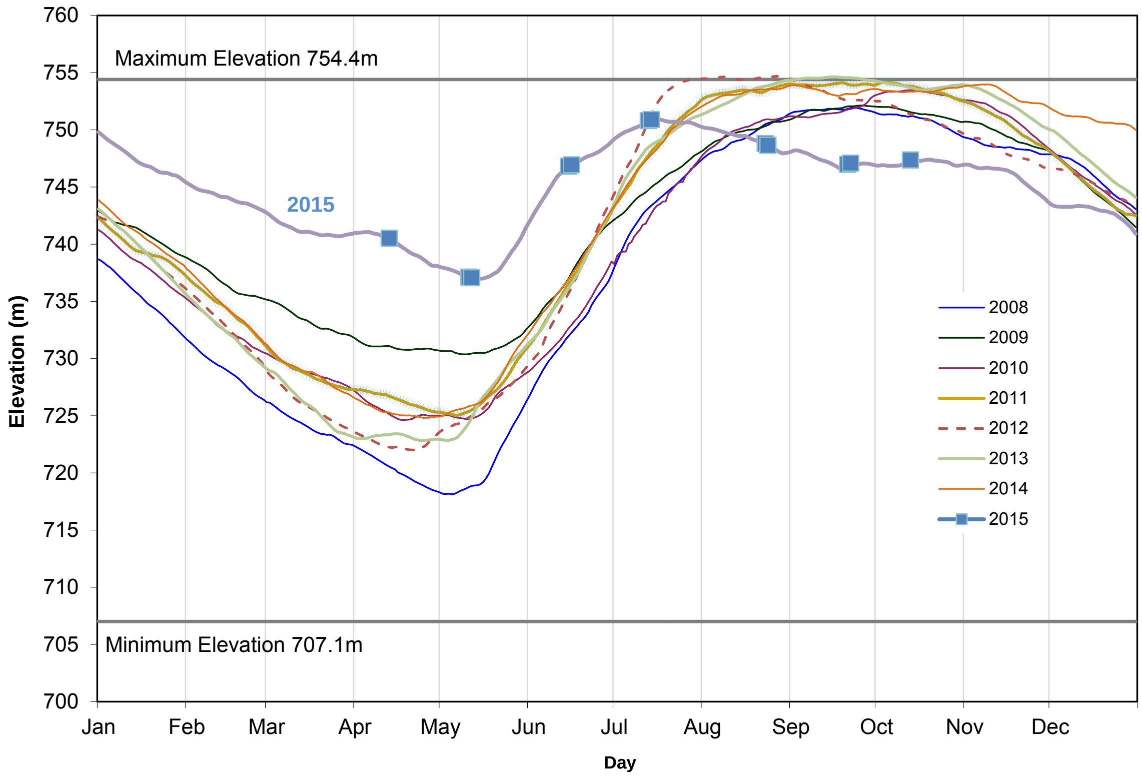


Figure 2. Kinbasket Reservoir elevation and sampling dates, 2015. Elevations for 2008-2014 are shown for comparison.

Table 1. Summary of Kinbasket and Revelstoke Reservoirs field sampling program 2015.

Parameter (Analyses)	**Sampling Frequency**	**Method**	**Depth**	**Stations** (Figure 1)								
				KIN Forebay	**KIN Canoe**	**KIN Wood Arm**	**KIN Col Reach**	**KIN Main Pool**	**REV Upper**	**REV Middle**	**REV Forebay**	**Tribs**
Weather Station (temp, ppt, BP, RH, PAR, wind)	Hourly/daily	Fixed Data logger		Mica dam crest							Rev Dam crest	
Profile (DO, temp, cond, chl a, PAR, turbidity) +Secchi	**Apr-Oct** Monthly (7)	Seabird +Secchi	0 to 60m+ (to within 5 m of bottom)	√	√	√	√	√	√	√	√	
Water Chem - Reservoir (TP, SRP, TDP, cond, NO_2+NO_3, alk, pH, turb) (silica)	**Apr-Oct** Monthly (7)	Bottle, tube	2,5,10,15,20, 40, 60, 80m and 5m off bottom 0-20m for Si	√	√	√	√		√	√	√	
Water Chem - Tributary (TP, SRP, TDP, cond, NO_2+NO_3, pH, alk, turb, temp)	5 reference tribs* once in A/S/O/N and twice in M/J/J	Bucket	Surface grab									√
Temperature - Tributaries	Hourly	Data logger	Ref tribs* + Bush R, Camp Ck									√
Temperature - Reservoir	Continuous	Data logger	Moored arrays, surface to bottom	√					√	√	√	
Phytoplankton	**Apr-Oct** Monthly (7)	Bottle	2, 5, 10, 15, 25 m	√	√	√	√		√	√	√	
Bacteria	**Apr-Oct** Monthly (7)	Bottle	Two composites of 2,5,10m and 15,20,25m	√	√	√	√		√	√	√	
Zooplankton	**Apr-Oct** Monthly (7)	Wisconsin net 2 hauls per site	0-30m	√	√	√	√		√	√	√	
C^{14}	**June-Sep** Monthly (4)	3 size fractions	0,1,2,5,10,12,15m	√**						√	√	

* Columbia River at Donald, Beaver River, Mica outflow, Goldstream River, Revelstoke outflow
**Note that station for PP is farther out towards the main pool than the regular sampling station in the forebay.

3.0 References

BC Hydro. 2005. Columbia River Project Water Use Plan Consultative Committee Report. Volumes 1 and 2. Prepared on behalf of the Consultative Committee for the Columbia River Water Use Plan. July 2005.

BC Hydro. 2007a. Columbia River Projects Water Use Plan. Revised for Acceptance by the Comptroller of Water Rights. BC Hydro. 41 pp + appendix. http://www.bchydro.com/content/dam/hydro/medialib/internet/documents/environment/pdf/wup_columbia_water_use_plan_revised_for_acceptance_by_th.pdf

BC Hydro. 2007b. CLBMON-3 Kinbasket and Revelstoke Reservoirs Ecological Productivity Monitoring Terms of Reference. BC Hydro dated October 24, 2007. http://www.bchydro.com/content/dam/hydro/medialib/internet/documents/environment/pdf/wup_clbmon_03_kinbasket_and_revelstoke_ecological_produc.pdf

BC Hydro. 2010. Kinbasket and Revelstoke Reservoirs Ecological Productivity Monitoring. Progress Report Year 1 (2008). BC Hydro, Water Licence Requirements. Study No. CLBMON-3. 4pp. + appendices. http://www.bchydro.com/content/dam/hydro/medialib/internet/documents/planning_regulatory/wup/southern_interior/clbmon-3_yr1_jan_2010.pdf

BC Hydro. 2011a. Kinbasket and Revelstoke Reservoirs Ecological Productivity Monitoring. Progress Report Year 2 (2009). BC Hydro, Water Licence Requirements. Study No. CLBMON-3. 4pp. + appendices. http://www.bchydro.com/content/dam/hydro/medialib/internet/documents/planning_regulatory/wup/southern_interior/2011q1/clbmon-3_yr2_2011-01-01.pdf

BC Hydro. 2011b. CLBMON-56 Addendum #1 to CLBMON-3 Kinbasket and Revelstoke Reservoirs Ecological Productivity Monitoring Program - Mica Project Units 5 and 6 Addendum. BC Hydro dated August 10, 2011. http://www.bchydro.com/content/dam/hydro/medialib/internet/documents/planning_regulatory/wup/southern_interior/2011q4/clbmon-56_addendum-1.pdf

Bray, K. E. 2012. Kinbasket and Revelstoke Reservoirs Ecological Productivity Monitoring. Progress Report Year 3 (2010). BC Hydro, Environment. Study No. CLBMON-3. http://www.bchydro.com/content/dam/hydro/medialib/internet/documents/planning_regulatory/wup/southern_interior/2012q1/clbmon-3_yr3_2012-01-01.pdf

Bray, K. E. 2013. Kinbasket and Revelstoke Reservoirs Ecological Productivity Monitoring. Progress Report Year 4 (2011). BC Hydro, Environment. Study No. CLBMON-3. http://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/corporate/environment-sustainability/water-use-planning/southern-interior/clbmon-3-yr4-2013-01-01.pdf

Bray, K.E. 2014. Kinbasket and Revelstoke Reservoirs Ecological Productivity Monitoring. Progress Report Year 5 (2012). BC Hydro, Environment. Study No. CLBMON-3 and CLBMON-56. https://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/corporate/environment-sustainability/water-use-planning/southern-interior/clbmon-3-clbmon-56-yr5-2014-11-01.pdf

Bray, K.E. 2016a. Kinbasket and Revelstoke Reservoirs Ecological Productivity Monitoring. Progress Report Year 7 (2014). BC Hydro, Environment. Study No. CLBMON-3 and CLBMON-56.

Bray, K.E. 2016b. Kinbasket and Revelstoke Reservoirs Ecological Productivity Monitoring. Progress Report Year 6 (2013). BC Hydro, Environment. Study No. CLBMON-3 and CLBMON-56. https://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/corporate/environment-sustainability/water-use-planning/southern-interior/clbmon-3-clbmon-56-yr6-2016-01-01.pdf

Bray, K., D. Sebastian, T. Weir, R. Pieters, S. Harris, D. Brandt, L. Vidmanic. 2013. Kinbasket and Revelstoke Reservoirs Ecological Productivity and Kokanee Population Monitoring 2008-2011 Synthesis Report. BC Hydro. Study Nos. CLBMON-3 and CLBMON-2. 91 pp. http://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/corporate/environment-sustainability/water-use-planning/southern-interior/clbmon-2-clbmon-3-yrs1-4-2013-06-01.pdf

Appendix 1

Hydrology of Kinbasket and Revelstoke Reservoirs, 2015

Roger Pieters, Thea Rodgers, and Greg Lawrence
University of British Columbia

Hydrology of Kinbasket and Revelstoke Reservoirs, 2014-2015

Roger Pieters[1,2], Thea Rodgers[1], and Greg Lawrence[2]

[1] Earth and Ocean Sciences, University of British Columbia, Vancouver, B.C. V6T 1Z4
[2] Civil Engineering, University of British Columbia, Vancouver, B.C. V6T 1Z4

Revelstoke Reservoir, 28 May 2015

Prepared for

Karen Bray
British Columbia Hydro and Power Authority
1200 Powerhouse Road
Revelstoke B.C. V0E 2S0

November 10, 2016

Contents

List of Figures

1. Introduction

The hydrology of Kinbasket and Revelstoke Reservoirs is described, focusing on flow in 2014-2015. This report updates Pieters et al (2016) and provides context for the ongoing BC Hydro project entitled "Kinbasket and Revelstoke Ecological Productivity Monitoring (CLBMON-3 and CLBMON-56)".

The upper Columbia River is defined in Figure 1.1 as the flow of the Columbia River near the Canada-US border, excluding the Pend Oreille River which joins the Columbia just above the border. Also excluded are the Kettle, Okanagan and Similkameen Rivers which join the Columbia in Washington State. As shown in Table 1.1, the upper Columbia accounts for only 13% of the total area drained by the Columbia River, but contributes 27% of the total flow in the Columbia River. Kinbasket and Revelstoke Reservoirs account for 4% of the area of the Columbia, and contribute 11% of the flow.

Table 1.1 Drainage area, mean flow and yield of selected regions of the Columbia River

	Drainage area (km^2)	**Flow (m^3/s)**	**Yield* (m/yr)**
Kinbasket and Revelstoke Reservoirs (WSC 08ND011 1955-1986)	26,400	796	0.95
Upper Columbia, Figure 1.1 (WSC 08NE058 minus 08NE010)	89,700	2,047	0.72
Columbia River (Kammerer, 1990)	668,000	7,500	0.35

*Annual water yield gives the total volume of river water leaving a catchment. Rather than express the volume in m^3, the yield is commonly given as the average depth of water spread over the entire catchment area, here given in m. The yield can be thought of as the average precipitation minus evapotranspiration over the catchment.

The headwater of the Columbia River begins in wetlands adjoining Columbia Lake, Figure 1.1. The Columbia River flows north-west through Windermere Lake and into Kinbasket Reservoir. Just before Mica Dam the Columbia River turns almost 180 degrees and flows south, through Mica Dam, through Revelstoke Reservoir, and then into the Arrow Lakes Reservoir.

Basic characteristics of Kinbasket and Revelstoke Reservoirs are compared to other major lakes and reservoirs from the Upper Columbia in Table 1.2. Kinbasket and Revelstoke Reservoirs are shown in greater detail in Figures 1.2 and 1.3, respectively. The approximate lengths of the reservoirs and their reaches are given in Table 1.3.

2. Annual Water Balance

Kinbasket Reservoir

Kinbasket Reservoir is shown in Figure 1.2. To the southeast, the Columbia River enters the Columbia Reach of Kinbasket Reservoir about 15 km downstream of Donald Station.

To the northwest, the Canoe River enters the Canoe Reach near the town of Valemount. These two long, narrow reaches join near Mica Dam.

Table 1.2 Characteristics of major lakes and reservoirs of the Upper Columbia

	Dam	Dam Completed (year)	Dam Height (m)	Max. Depth (m)	Max. Area (km^2)	Mean Outflow (m^3/s)
Kinbasket	Mica	1973	244	*~185*	425	590
Revelstoke	Revelstoke	1984	175	*~125*	115	750
Arrow	Keenleyside	1968	52	290/190	520	1,080
Koocanusa	Libby	1973	95	107	186	350
Duncan	Duncan	1967	39	147	75	90
Kootenay	Cora Linn	1931	38	154	390	780

	Drawdown (m)	Drawdown Area (km^2)	Drawdown Area (% full)
Kinbasket	47	220	50%
Revelstoke	1.5	2.4	2%
Arrow	20	159	30%
Koocanusa	52		
Duncan	28		
Kootenay	3		

The water balance for Kinbasket Reservoir is given in Table 2.1. Also given is the annual water yield from the drainage. The yield is the average annual outflow divided by the drainage area. The local inflow to Kinbasket Reservoir has about twice the yield as the Columbia River above Donald, indicating increased precipitation in the local drainage to Kinbasket Reservoir.

Table 1.3 Length of reservoirs

Reservoir	**Length (km)**
Kinbasket Reservoir	190
Columbia Reach	100
Canoe Reach	90
Revelstoke Reservoir	130
Upper Revelstoke	80
Lower Revelstoke	50
Arrow Lakes Reservoir	210
Revelstoke Reach	40
Upper Arrow	60
Narrows	30
Lower Arrow	80
Kootenay Lake	110

Local inflow to Kinbasket dominates the water balance, contributing 66% of the inflow. In contrast, the Canoe River, while having a high yield, contributes only 3% due to its relatively small drainage.

Table 2.1 Annual water balance for Kinbasket Reservoir

		Area (km^2)	Flow (m^3/s)	Yield (m/yr)
Qin	Columbia R. at Donald Station	9,710 (45%)	172 (30%)	0.56
Qin	Canoe River near Valemount	368 (2%)	19* (3%)	1.6*
Qloc	Local Flow into Kinbasket	11,422 (53%)	376 (66%)	1.0
Qout	Columbia River at Nagle Creek (Mica Dam Outflow)	21,500	567	0.83

*Estimated from partial data for 1966-1967.

Prior to Mica Dam, most of Kinbasket Reservoir was river, with the exception of Kinbasket Lake which was approximately 10 km long, located near Kinbasket Creek on the Columbia Reach. Water Survey of Canada (WSC) had gauges at several sites along what would become Kinbasket Reservoir, shown in Figure 1.2 (red squares). The data from these sites (Appendix 1) allow the division of Kinbasket Reservoir into the regions given in Table 2.2. The inflow of the Upper Columbia Reach is particularly large, matching the inflow of the Columbia River at Donald.

Table 2.2 Drainage, flow and yield of regions in Kinbasket Reservoir

	Canoe River	Canoe Reach	Wood Arm	Lower Columbia Reach[1]	Upper Columbia Reach[2]	Columbia River Above Donald
Drainage (km^2)	368	2,922	956	3,250	4,290	9,710
Inflow (m^3/s)	~19	86	40	85	165	172
Yield (m/yr)	~1.6	0.93	1.3	0.82	1.2	0.56
% of outflow	3%	15%	7%	15%	29%	30%

[1] Between Mica Dam and the Columbia River at Surprise Rapids
[2] Between the Columbia River at Surprise Rapids and Columbia River at Donald

Revelstoke Reservoir

Revelstoke Reservoir is shown in Figure 1.3. The entire length was formerly a river and the resulting reservoir is very narrow. The water balance for Revelstoke Reservoir is given in Table 2.3. For Revelstoke, the outflow from Mica Dam is the dominant inflow (71%) to the reservoir. While the local drainage area to Revelstoke Reservoir is relatively small, the higher yield of this drainage means that the local inflow still contributes 29% to the total outflow.

Table 2.3 Annual water balance for Revelstoke Reservoir

	Area (km^2)	Flow (m^3/s)	Yield (m/yr)
Columbia River at Nagle Creek (Mica Dam Outflow)	21,500 (81%)	567 (71%)	0.83
Local Flow into Revelstoke	4,900 (19%)	229 (29%)	1.47
Columbia River above Steamboat Rapids (Revelstoke Outflow)	26,400	796	0.95

Unlike Kinbasket Reservoir, no WSC data were available for the Columbia River along what would become Revelstoke Reservoir. While WSC lists a station "Columbia River above Downie Creek" (08ND010), no data were available at this site. We divide Revelstoke Reservoir just above Downie Creek (Figure 1.3) into upper and lower reaches assuming the same yield to each, see Table 2.4. Note the drainage to the lower Revelstoke reach is relatively small.

Table 2.4 Drainage, flow and yield of regions in Revelstoke Reservoir

	Mica Outflow (Columbia above Nagle)	Upper Revelstoke Reach[1]	Lower Revelstoke Reach
Drainage (km^2)	21,500	*3,300*	*1,600*
Inflow (m^3/s)	567	*155*	*75*
Yield (m/yr)	0.83	*1.5*	*1.5*
Of outflow (%)	71%	*19%*	*9%*

[1] The boundary between upper and lower was chosen above Downie Creek.
Values in italics are approximate.

3. Columbia River at Donald

Data

Daily flow data were available for 1944-2015 from WSC station 08NB005, entitled "Columbia River at Donald". This station is located roughly 15 km upstream of Kinbasket Reservoir.

Results

Figure 3.1a shows the daily flows for 1944-2015. The mean daily hydrograph shown in Figure 3.1b peaks from early June to mid-July at roughly 550 m^3/s, tapering through the summer and fall to a base flow in the winter of approximately 35 m^3/s. The mean annual flow for 1944-2015 was 171 m^3/s.

The daily flows are shown in Figure 3.2 for years 2000-2015, which include the years with hydroacoustic surveys of kokanee abundance (2003-2015). Also shown for comparison in each panel is the daily mean flow for 1944-2015. The flows generally followed the mean; exceptions include the following: in late fall of 2003 the flow rose to about 4 times the seasonal average; in 2006 and 2007 the flows in the late spring were above average; in 2004, 2009 and 2010 the summer flows were below average. In late September 2010, around the time of kokanee counts, there was a relatively large peak in flow likely the result of a rainfall event (Figure 3.2.2c). In 2012, flow from June until mid-August was much higher than average (Figure 3.2.2e).

4. Columbia River at Mica Dam

Data

Data were available for 1947-1983 from WSC station 08ND007, entitled "Columbia River above Nagle Creek". This station is located approximately 3 km downstream of Mica Dam. Data for the Mica Dam Outflow were available for 1971-2015 from BC Hydro. The WSC data from "Columbia River above Nagle Creek" were used for 1947-1975 and the BC Hydro data were used for 1976-2015.

Results

Pre- and post-impoundment flows are shown in Figure 4.1a. The change in flow after completion of Mica Dam in 1973 is evident. Before impoundment, the hydrograph had a large single peak of roughly 1600 m^3/s from early June to mid-July (Figure 4.1b). The flow gradually declined in the summer and fall until it reached a low base flow in the winter of around 120 m^3/s. After Mica Dam was completed, the spring peak flow was reduced and replaced with a more variable flow throughout the year (Figure 4.1c). During snowmelt in spring, the outflow from the Reservoir is generally low, and most of the freshet inflow is stored in the reservoir. However, once the reservoir has almost filled, outflow is increased, thereby releasing the tail of the freshet and resulting in an increase in flow during the late summer. A second broad peak occurs during the winter as water is released for hydroelectric generation.

The discharge from Mica Dam for 2000-2015 is shown in Figure 4.2. While the flow over the years shown has generally followed the mean, the flow from mid-May to mid-July was often below average with long stretches close to zero. In 2015 the flow is unusual, with significantly higher flows from April to mid-May and mid-June to mid-September. In some years, outflow was also below average through late summer and early fall, e.g. 2008, 2009, 2010 and 2013.

5. Columbia River at Revelstoke Dam

Data

Daily flow data from two WSC stations were used for the Columbia River near Revelstoke Dam. For 1955-1985, data were available from WSC station 08ND011, entitled “Columbia River above Steamboat Rapids”. This station is located roughly 1.5 km downstream of Revelstoke Dam. For 1986-2015, data were available from WSC station 08ND025, entitled “Revelstoke Project Outflow”.

Results

The daily discharge for 1955-2015 is shown in Figure 5.1a. The change in flow due to the completion of the upstream Mica Dam in 1973 is evident. There is no obvious change in the daily flow upon the completion of Revelstoke Dam in 1984 as it is operated run of the river. The mean daily pre-impoundment hydrograph given by the data from the Columbia River above Steamboat Rapids is shown in Figure 5.1b. The post-impoundment hydrograph given by the data from the Revelstoke Project Outflow is shown in Figure 5.1c.

Similar to that seen for the pre-impoundment flow at Mica Dam, the pre-impoundment outflow at Revelstoke showed a spring peak of about 2800 m^3/s which declined through the summer and fall until it reached a winter base flow of under 300 m^3/s (Figure 5.1b). Post-impoundment outflow is distributed more evenly throughout the year with minor peaks in the summer and winter (Figure 5.1c).

The Revelstoke discharge for 2000-2015 is shown in Figure 5.2, and generally follows the mean post-impoundment hydrograph. Two particular exceptions were July to September 2010 when outflow was below average, and mid-July to mid-August 2012 when outflow was far greater than average, including spill. Like the outflow from Kinbasket Reservoir, the outflow from Revelstoke was significantly higher from May to September 2015.

6. Local Metered Inflow

Data

Of the rivers and streams in the Kinbasket and Revelstoke drainage, few have been gauged by Water Survey Canada. Those that have been gauged are listed in Appendix 1. Beaver River, Gold River, and Goldstream River are all currently gauged and will serve as examples of tributary inputs. Although the Illecillewaet River enters the Columbia River about 10 km downstream of Revelstoke Dam, it is included as an example of a gauged tributary because of its proximity, size, and long record of water quality data.

Results

Flow data for the four tributaries are summarized in Table 6.1. Figures 6.1-6.4 show the (a) daily and (b) mean flow for each tributary. The hydrographs of all of the tributaries are compared for each of the years 2008 to 2015 in Figures 6.5 to 6.12, respectively, along with those of the Columbia River at Donald and the Columbia River at Revelstoke. The hydrographs for the tributaries are very similar, and generally resemble the flow of the uncontrolled Columbia River at Donald. Note that above average flows in June and July 2012 occurred at all sites.

Table 6.1 Gauged tributaries flowing into the Columbia River

Station #	Station Name	Year	Drainage Area (km^2)	Annual Mean Flow (m^3/s)	Yield (m/yr)
08NB019	Beaver River near the Mouth	1985-2015	1150	42.1	1.16
08NB014	Gold River above Palmer Creek	1973-2015	427	18.2	1.35
08ND012	Goldstream River below Old Camp Creek	1954-2015	938	39.0	1.31
08ND013	Illecillewaet River at Greeley	1963-2015	1170	52.9	1.42

7. Kinbasket Reservoir Water Level

Data

Daily water level data were available for 1974-2015 from WSC station 08ND017, entitled “Kinbasket Lake at Mica Dam”. This station is located in Kinbasket Reservoir near Mica Dam.

Daily water level data were also available for 1980-2015 from WSC station 08NB017, entitled “Kinbasket Lake below Garrett Creek”. This station is located about 55 km southeast of Mica Dam in the Columbia Reach. Since both stations are on Kinbasket Reservoir, the water levels are expected to be comparable. The difference between the two stations was generally less than 0.5 m (standard deviation 0.2 m), except for April 2-30, 2007, when data at Kinbasket Lake at Mica Dam had a large (3 m) offset; these data were replaced with that from Kinbasket Lake below Garrett Creek.

Results

Figure 7.1a shows the daily water level of Kinbasket Reservoir for 1974-2013. Note the rise in water level in the first two years following the completion of the dam in 1973. Figure 7.1b shows the mean daily post-impoundment water level for 1977-2015.

The water level in Kinbasket Reservoir for 2000-2015 is shown in Figure 7.2 and generally followed the post-impoundment mean level with a few exceptions: in 2001 and 2003 the water level was below average for the entire year, and in 2004 the water level was below average from January to mid-October. In 2012, the water level was slightly below average from March to June, but rose to above average (including surcharge) for July to September. Similarly in 2013, the water level was slightly below average from March to May, but was above average for the remainder of the year with brief surcharge in September 2013. In 2015, water level was not drawn down as quickly or as far as in previous years, and as a result, the water level was above average for January to July.

Figure 7.3 shows the annual minimum and maximum water level for Kinbasket Reservoir, 1977-2015. While the difference between the normal maximum and normal minimum water level is 47 m (754.38 to 707.41 m ASL), drawdown in any given year averages 25 m. There are periods of time when the water level is relatively low throughout the year (e.g. 1992-1994) and at other times it is relatively high (e.g. during the study period 2008-2015). The minimum and maximum water levels are shown in Figure 7.3b. The area of the reservoir at minimum water level was 240 to 320 km^3, only 55-75% of the area at maximum water level later in the year. Also shown are the dates at which the reservoir reached minimum pool in late April, and 90% of full pool in late July (Figure 7.3c). From 2008-2011 and in 2015, the minimum water level occurred significantly later than average (red, Figure 7.3c). In 2015, the reservoir remained at very high water level, which had not been seen since early 1983 (red, Figure 7.3b).

8. Revelstoke Water Level

Data

Daily water level data were available for 1984-2015 from the BC Hydro station located in the Revelstoke forebay.

Results

Figure 8.1a shows the water level of Revelstoke Reservoir for 1984-2015. Note the change in water level due to the completion of the dam in 1984. Figure 8.1b shows the mean daily post-impoundment water level averaged from 1988-2015. The water level varies by only a few meters, as the reservoir is operated run of the river.

The water level for years 2000-2015 is shown in Figure 8.2, together with the mean post-impoundment level averaged from 1988-2015. The water levels generally followed the post-impoundment mean levels. From 2012 to early 2014 there were a number of brief drawdowns below normal minimum, for example in January and November 2013 (Figure 8.2.2f). Water levels below normal minimum were not observed through the rest of 2014 or in 2015.

9. Flow to storage

Data

Storage flow gives the rate of change of the volume of the reservoir; when the storage flow is positive, the water level rises and the volume of the reservoir increases. The volume was determined from the water level at the forebay using the storage elevation curves provided by BC Hydro (Appendix 3). The storage flow, for day i was computed using centered differences as,

$$Q_{stor}^{i} = \frac{V^{i} + V^{i+1}}{2} - \frac{V^{i-1} + V^{i}}{2} = \frac{V^{i+1} - V^{i-1}}{2}.$$

Note the storage flow is a small difference of large values, and can be noisy.

Results

The storage flow for Kinbasket Reservoir is shown in Figure 9.1a for 1976-2015. The average flow is shown in Figure 9.1b; the average flow is positive during the spring and summer as the reservoir fills, and negative through the remainder of the year as the water level falls. Daily storage flow for 2000-2015 is shown without smoothing in Figure 9.2. The flow in recent years, 2008 to 2014, generally followed the mean, although flow in 2012 was above average from June to July. In 2015, flow to storage was below average both in early spring (April to May) and late summer (July to August). The flow to storage was reduced because the water level had not drawn down as far as usual in spring 2015.

Revelstoke Reservoir is operated as run of the river with only small changes in water level (Figures 8.1 and 8.2). As a result, the storage flow for Revelstoke is small and noisy (not shown).

10. Local Inflow

Data

The local flow is composed of all inflow to the reservoir other than the main inflow. The local flow includes tributaries of all sizes, as well as the net precipitation to the surface of the reservoir. The local inflow was computed for both Kinbasket and Revelstoke Reservoirs using a water balance for inflows and outflows:

$$Q_{in} + Q_{loc} = Q_{stor} + Q_{out},$$

where Q_{in} is the main inflow, Q_{loc} is the local flow, Q_{stor} is the storage flow computed in the previous section, and Q_{out} is the outflow. The Columbia River at Donald is the main inflow (Q_{in}) to Kinbasket Reservoir, and the outflow from Mica Dam is the main inflow to Revelstoke Reservoir.

Like the storage flow, the local flow is a small difference of large values, is subject to considerable error, and can be very noisy. Large spikes in the data are often followed by a large correcting dip. While negative local inflow is not physical (water flowing up a river), the negative values shown balance the positive spikes.

Results

Figure 10.1 shows the annual and mean local flow for Kinbasket Reservoir. The mean (Figure 10.1b) follows the shape of the natural hydrograph seen in the Columbia at Donald (Figure 3.1). The peak in the local flow is about twice that of the Columbia at Donald, consistent with the annual water balance (Table 2.1).

Figure 10.2 shows the annual and mean local flow for Revelstoke Reservoir for 1989-2015. The mean hydrograph is consistent with that of local inflow, though it is noisier because there are fewer years of data than for Kinbasket Reservoir.

The annual local flow for both Kinbasket and Revelstoke Reservoirs is shown in Figure 10.3 for 2000-2015. The data were lightly filtered with three passes of a 3 point moving average, and were scaled by drainage area and yield for comparison to the Columbia River at Donald. The Columbia River at Donald and the two local flows show similar peaks across the three respective drainage areas. There are also some regional differences; for example in May 2008, the local freshet flow rises sooner in Kinbasket and Revelstoke Reservoirs than in the Columbia River at Donald (Figure 10.3.2a), and in July 2012 the local flow to Revelstoke Reservoir declined before the others (Figure 10.3.2e).

The local flow to Revelstoke Reservoir is compared to the main inflow to Revelstoke Reservoir of the Columbia from Mica Dam in Figure 10.4. From May to mid-July, when Kinbasket Reservoir is filling and the outflow from Mica Dam is low, the inflow to Revelstoke Reservoir is dominated by local inflow.

11. Summer 2008 to 2015

The El-Nino/Southern Oscillation ENSO index (Wolter, 2012) and the size of winter snow packs (BCRFC, 2016) are summarized in Table 11.1 for the study years.

Table 11.1 Summary of meteorological and hydrological conditions during study years

2008	Strong* La Nina (Jan - Mar 2008) Columbia Region Snow Basin Index (April 1st), 104% Flow slightly below average, sharp onset of freshet in mid-May Cool mid-March to mid-May
2009	Weak La Nina (Aug 2007 - Mar 2008) Columbia Region Snow Basin Index (April 1st), 78% Flow generally below average
2010	Strong El Nino (Jan - Mar 2010; winter Olympics) Columbia Region Snow Basin Index (April 1st), 84% Flow generally below average High inflow event during late September
2011	Strong La Nina (Jul 2010 - Apr 2011) Columbia Region Snow Basin Index (April 1st), 101% Flow average Consistently colder than average from late March to early May
2012	Weak El Nino (Apr 2012) Columbia Region Snow Basin Index (April 1st), 125% Local flow above average in late June and early July
2013	Weak La Nina (Jun - Aug 2013) Columbia Region Snow Basin Index (April 1st), 102% Flow average
2014	El Nino (Apr - Aug 2014) Upper Columbia Region Snow Basin Index (April 1st), 98% Flow average
2015	Strong El Nino (Mar - Dec 2015) Upper Columbia Region Snow Basin Index (April 1st), 86% Flow below average (after early and high freshet mid-May to mid-June) High inflow event during late September High outflow from Kinbasket Reservoir, April to September

* Strong is defined as one of the top 6 bi-months since 1950.

The summer, including those of 2008 to 2014 can be divided into two periods. From May to mid-July inflow to Kinbasket Reservoir is stored resulting in a rapid increase in water level (Figure 7.2.2) and little outflow (Figure 4.2.2). In 2010, this low outflow period extended to the end of July (Figure 4.2.2c). For Revelstoke Reservoir, downstream of Kinbasket, this means that the major inflow from May to mid-July is freshet inflow from local drainage. Because Revelstoke Reservoir is operated as run of the river (Figure 8.2.2), the outflow from Revelstoke Reservoir is driven by local freshet inflow during the periods of low Mica outflow.

In 2008, a strong freshet peak occurred in mid-May and again in early July (Figure 6.5). In 2009, freshet was more gradual, peaking in early and mid-June (Figure 6.6). In 2010, two early and short duration peaks occurred in April and May, followed by a broader peak later in June (Figure 6.7). In 2011, the flow was below average until mid-May (a cold spring) and freshet peaked at the end of June (Figure 6.8). In 2012, there was a large freshet peak from late June to mid-July (Figure 6.9). In 2013, despite the strong onset of freshet in mid-May, local inflow was approximately average through the remainder of the year. In 2014 and 2015, a freshet peaked in mid to late May (Figures 6.11 and 6.12).

The second period is mid-July to September, when Kinbasket Reservoir has almost filled and the tail of the freshet is discharged from Mica Dam (Figure 4.2.2). This increased flow from Kinbasket to Revelstoke makes up for the decline in local freshet inflow to Revelstoke; as a consequence, the discharge from Revelstoke is similar in both periods (Figure 5.2.2; Figure 10.4.2). Note that 2015 was an exception, as outflow from Mica Dam remained very high in mid-April to mid-May when it was low in previous years, and high from mid-June onward (Figure 4.2.2h).

Acknowledgements

We gratefully acknowledge funding provided by B.C. Hydro and the assistance of D. Robb, A. Akkerman, J. Bowman, A. Sharp and K. Lywe.

References

BCRFC (British Columbia River Forecast Centre). 2016. Snow Survey and Water Supply Bulletin. Accessed at http://bcrfc.env.gov.bc.ca/bulletins/.

Kammerer, J.C. 1990. Largest rivers in the United States. USGS Water Fact Sheet, Open File Report 87-242. http://pubs.usgs.gov/of/1987/ofr87-242/

Pieters, R., L.C. Thompson, L. Vidmanic, S. Harris, J. Stockner, H. Andrusak, M. Young, K. Ashley, B. Lindsay, G. Lawrence, K. Hall, A. Eskooch, D. Sebastian, G. Scholten and P.E. Woodruff. 2003. Arrow Reservoir fertilization experiment, year 2 (2000/2001) report. RD 87, Fisheries Branch, Ministry of Water, Land and Air Protection, Province of British Columbia.

Pieters R., A. Sharp, and G. Lawrence. 2016. Hydrology of Kinbasket and Revelstoke Reservoirs, 2013. Prepared for BC Hydro, Water Licence Requirements. 56 pp. Appendix 1 *in* Bray, K.E. 2016. Kinbasket and Revelstoke Reservoirs Ecological Productivity Monitoring. Progress Report Year 5 (2013). BC Hydro, Environment. Study No. CLBMON-3 and CLBMON-56.

Water Survey Canada. 2012. Hydat National Water Data Archive. Accessed at http://www.wsc.ec.gc.ca/products/hydat/main_e.cfm?cname=archive_e.cfm.

Wolter, K. 2012. Multivariate ENSO Index (MEI). Accessed at http://www.esrl.noaa.gov/psd/enso/mei/.

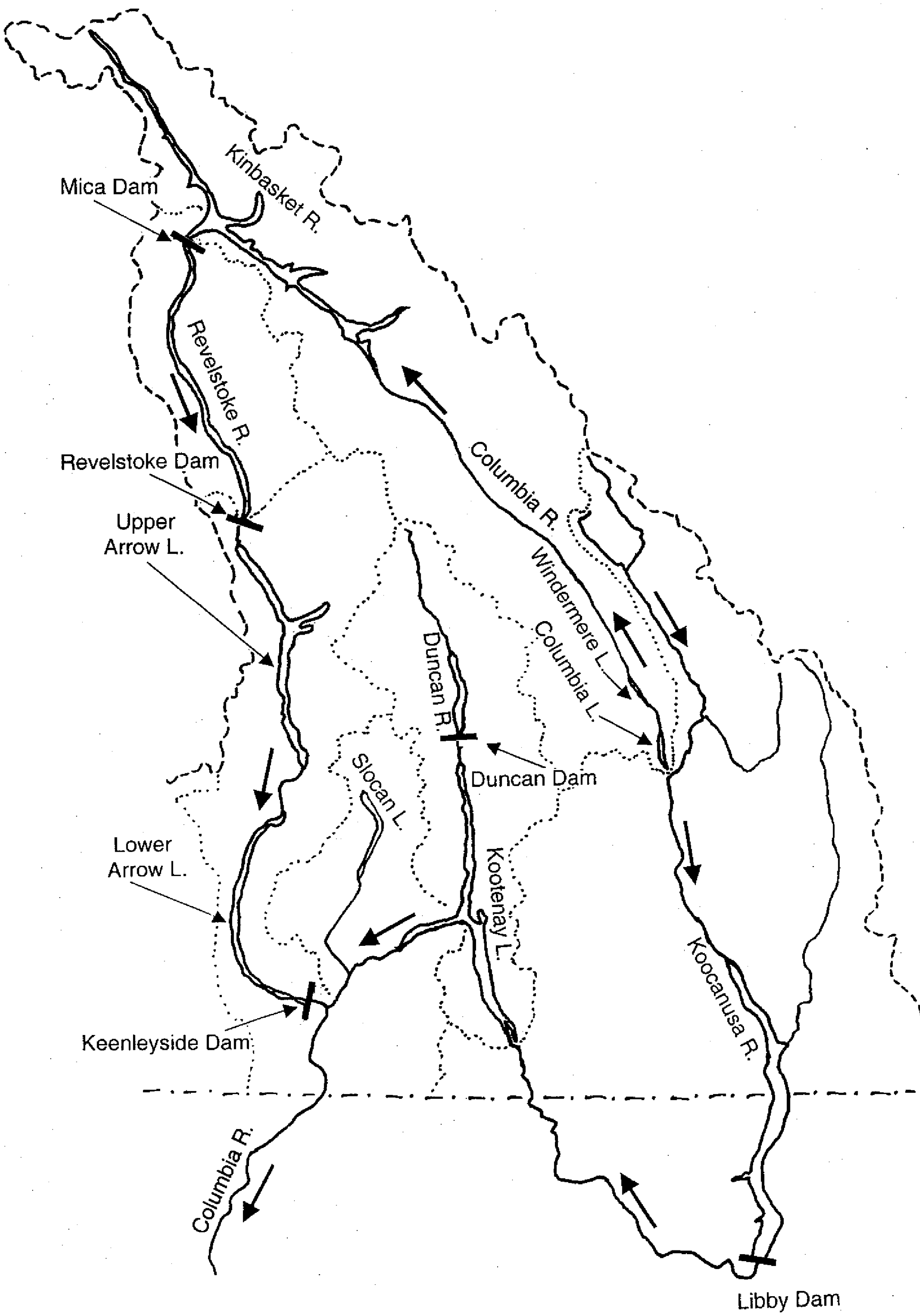


Figure 1.1. Upper Columbia River Basin

Figure 1.2 Kinbasket Reservoir with gauging stations (RED) and sampled tributaries (YELLOW).

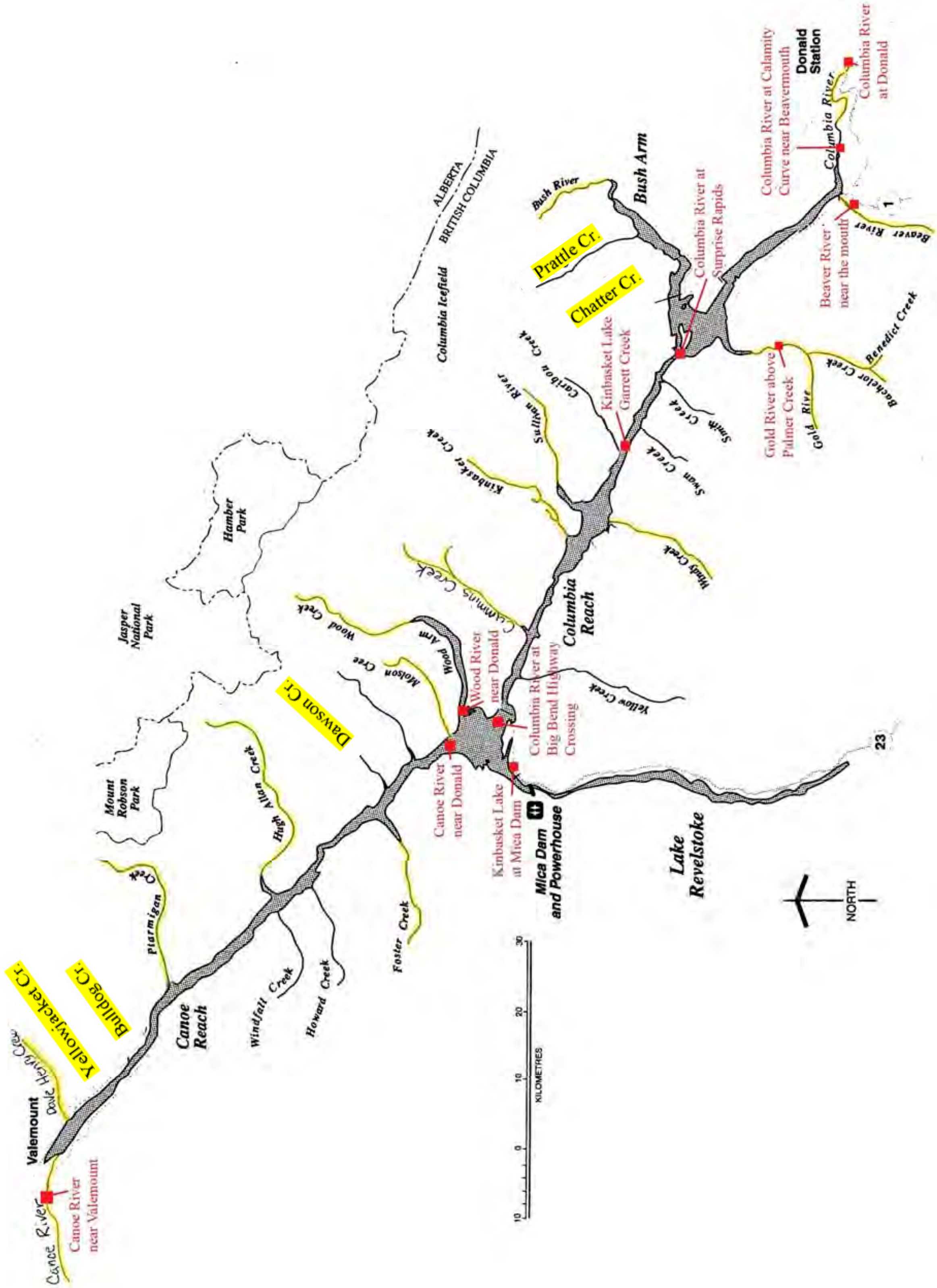
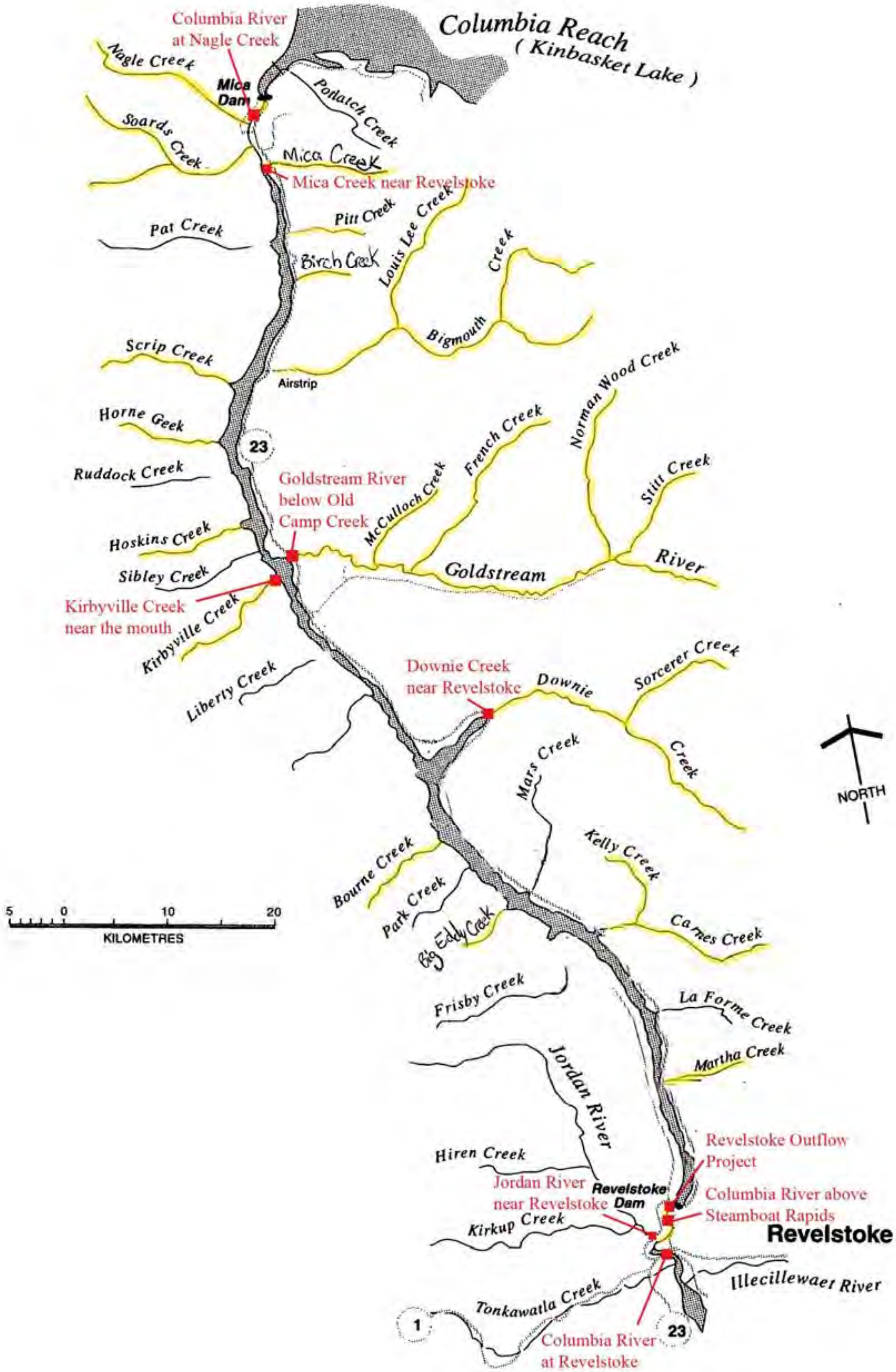


Figure 1.3 Revelstoke Reservoir with gauging stations (RED) and sampled tributaries (YELLOW).



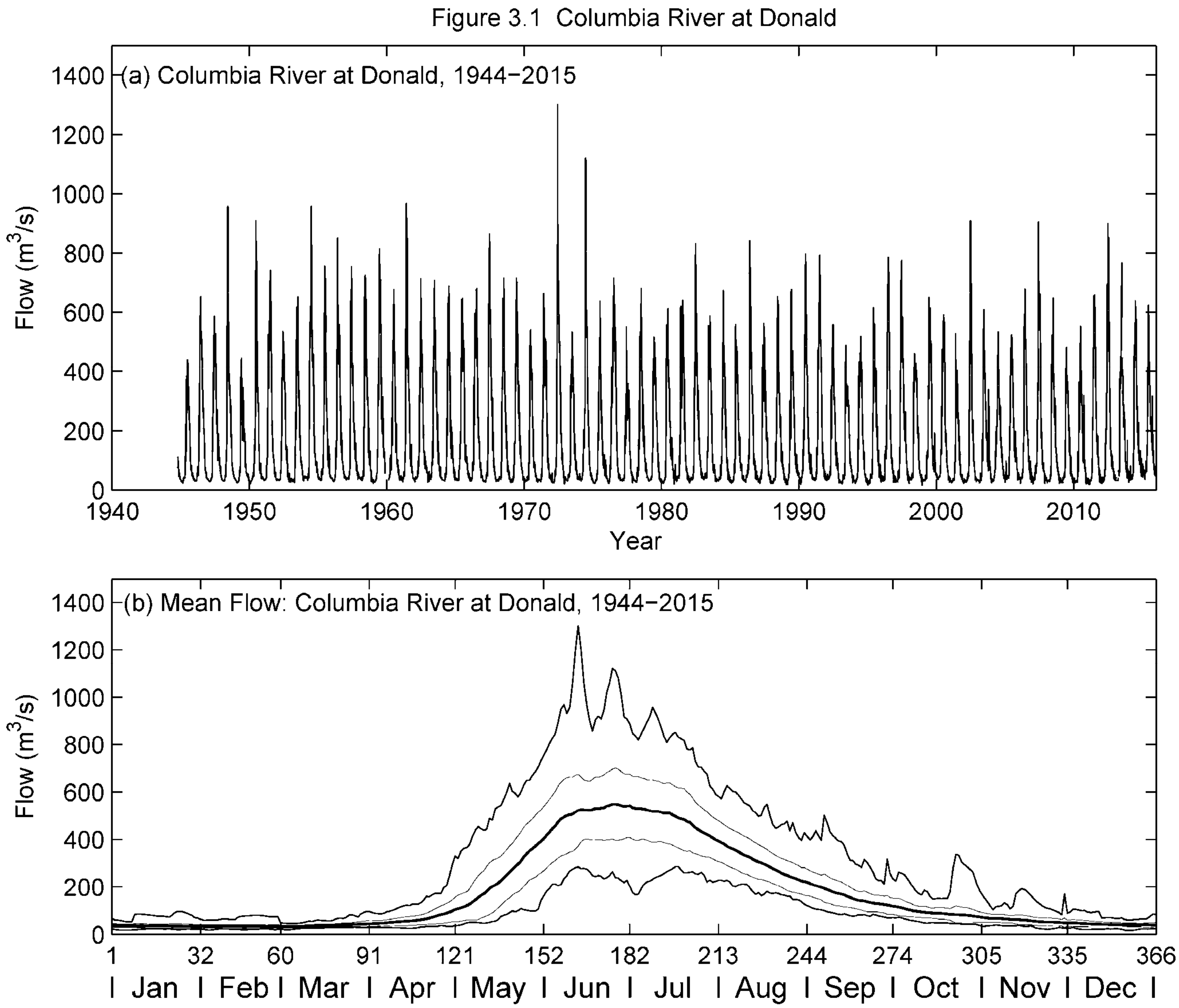


Figure 3.1. **(a)** WSC station 08NB005, "Columbia River at Donald", 1944-2013. **(b)** Mean flow for the years indicated. Mean (heavy line), maximum and minimum (medium lines) and mean ± one standard deviation (light lines).

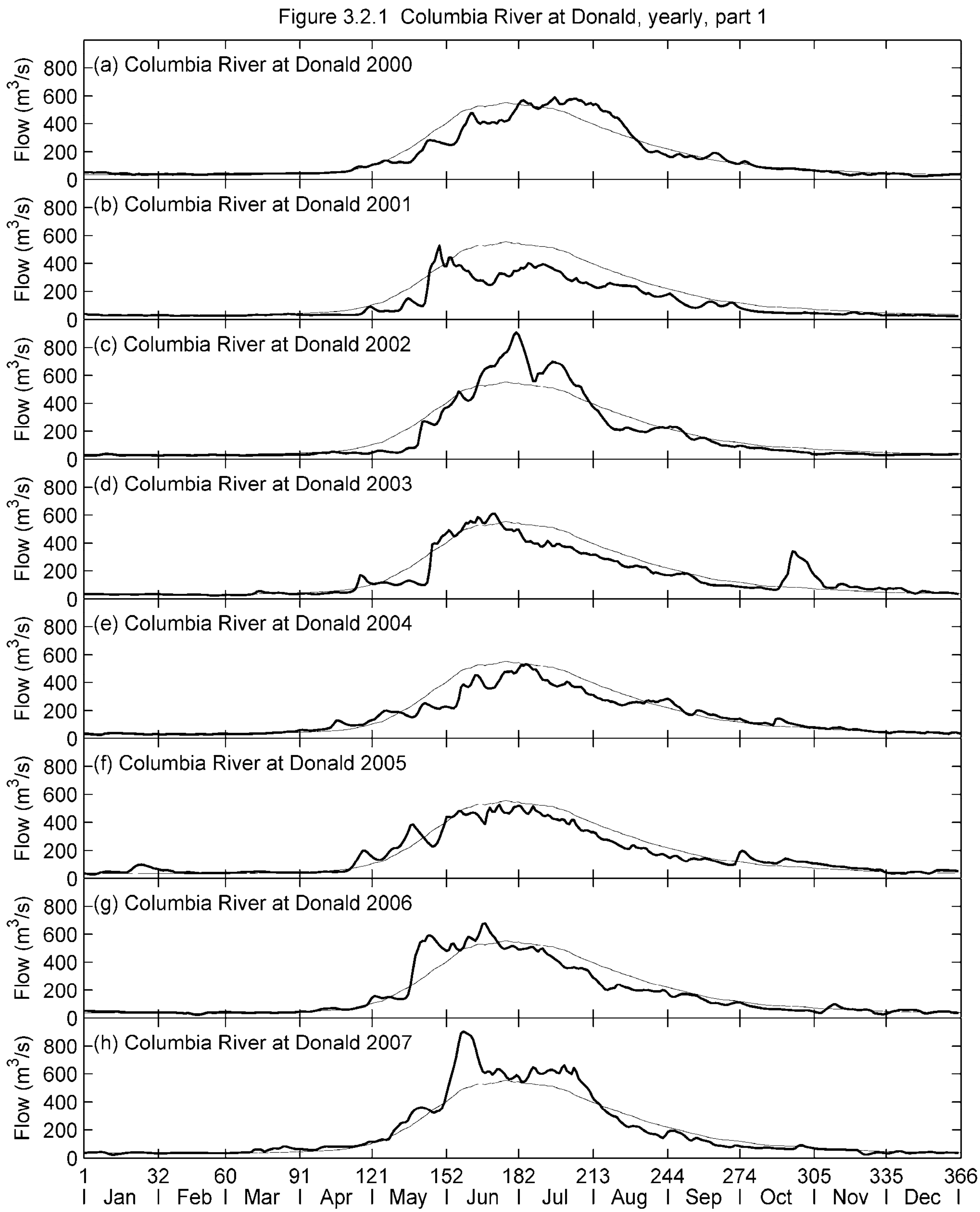


Figure 3.2.1. WSC station 08NB005, "Columbia River at Donald", selected years (heavy line). Mean flow for 1944-2013 (light line) is shown for comparison.

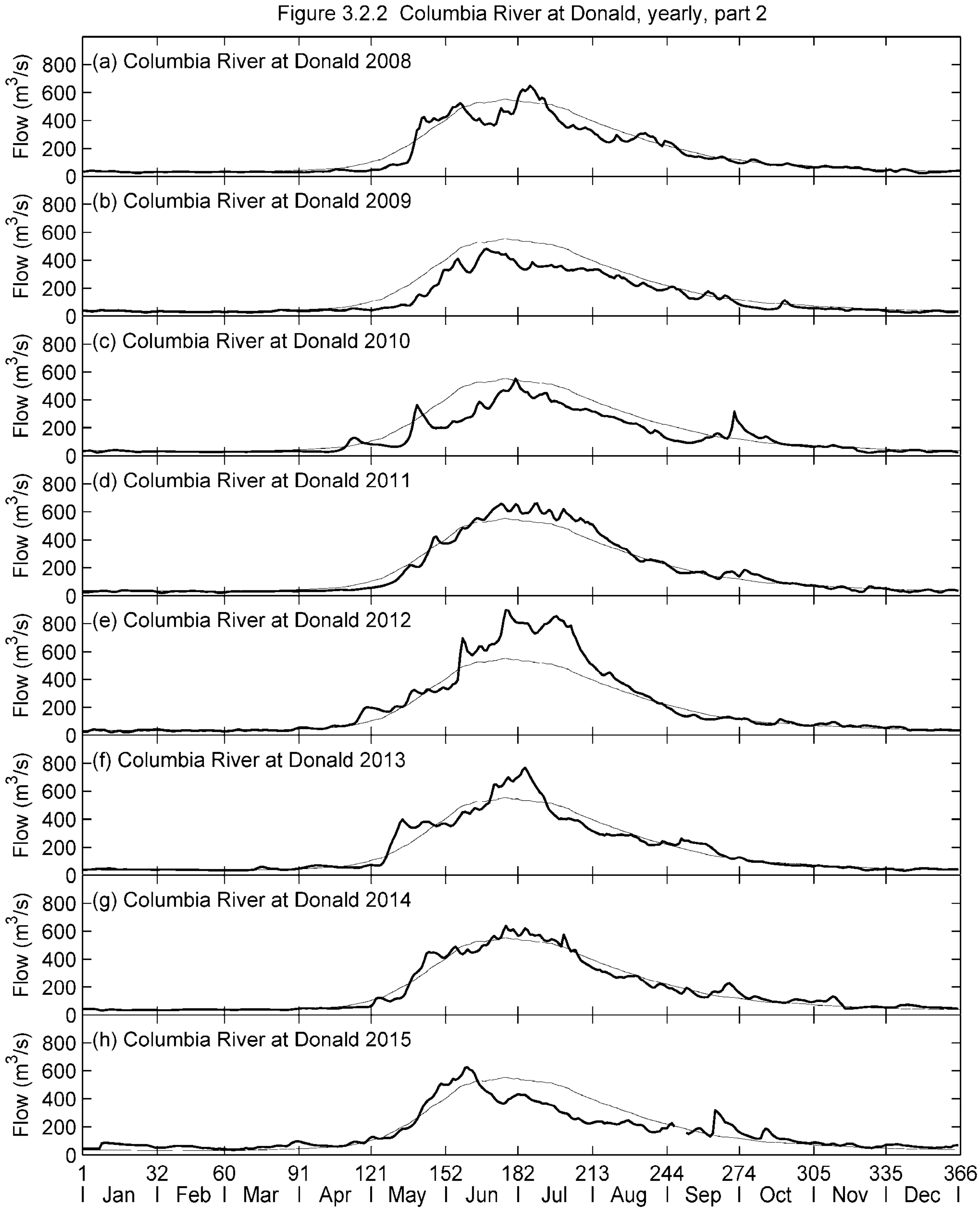


Figure 3.2.2. WSC station 08NB005, "Columbia River at Donald", selected years (heavy line). Mean flow for 1944-2013 (light line) is shown for comparison.

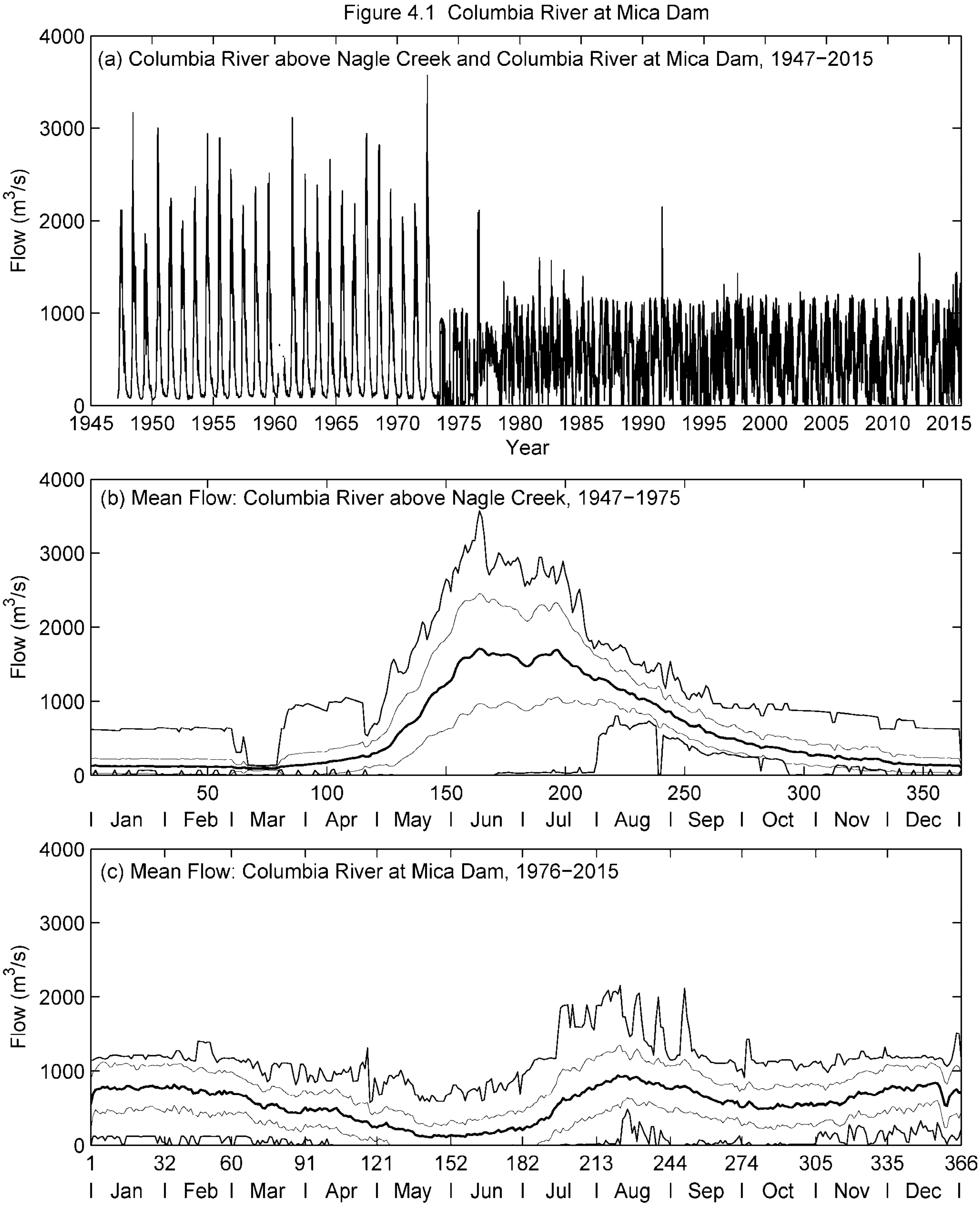


Figure 4.1. **(a)** WSC station 08ND007, "Columbia River above Nagle Creek", 1947-1975 and BC Hydro station "Columbia River at Mica Dam Outflow", 1976-2013. **(b)** Mean pre-impoundment flow for the years indicated. **(c)** Mean post-impoundment flow for the years indicated. Mean (heavy line), maximum and minimum (medium lines) and mean ± one standard deviation (light lines).

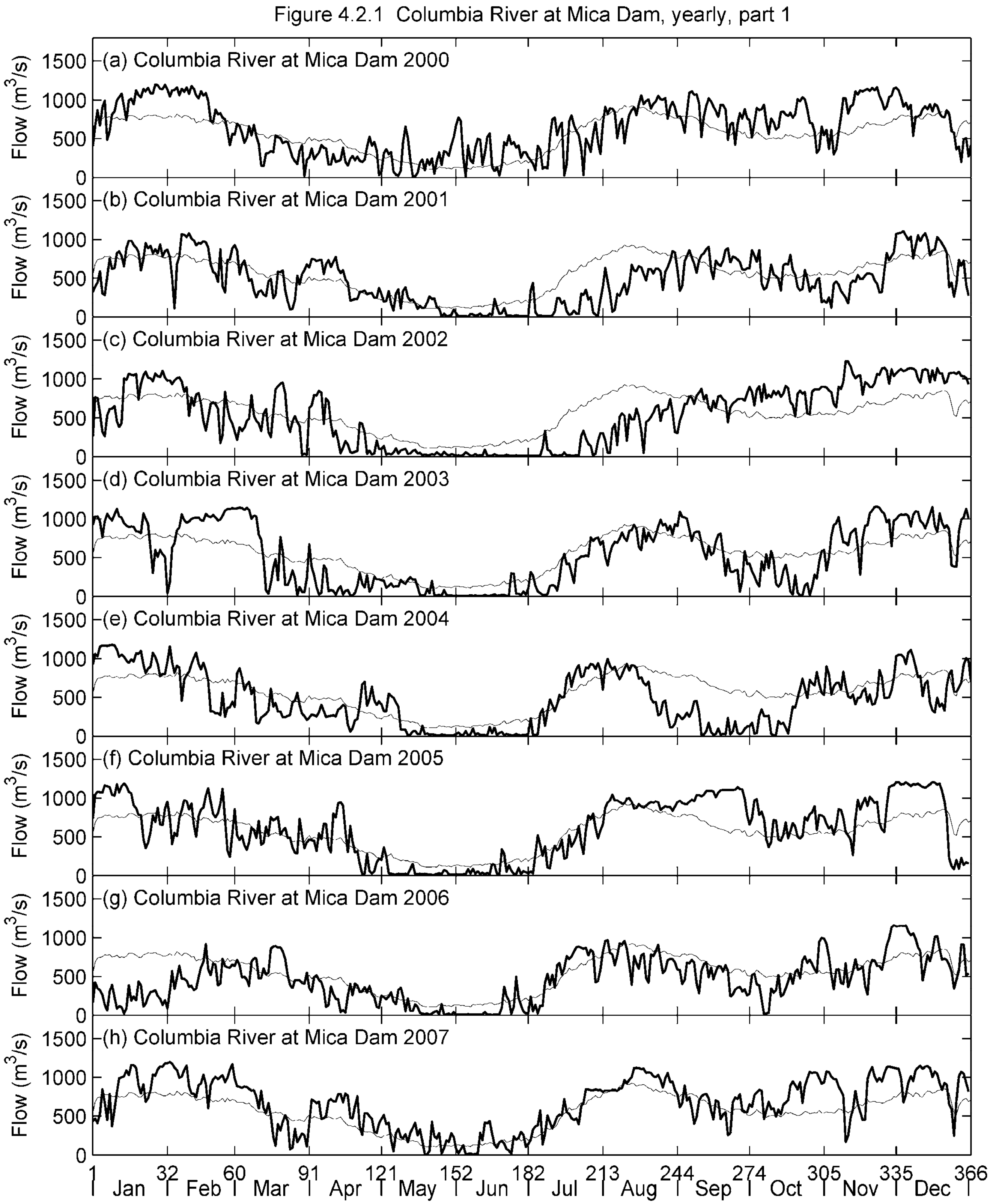


Figure 4.2.1. BC Hydro station "Columbia River at Mica Dam Outflow", selected years (heavy line). Mean flow for 1976-2013 (light line) is shown for comparison.

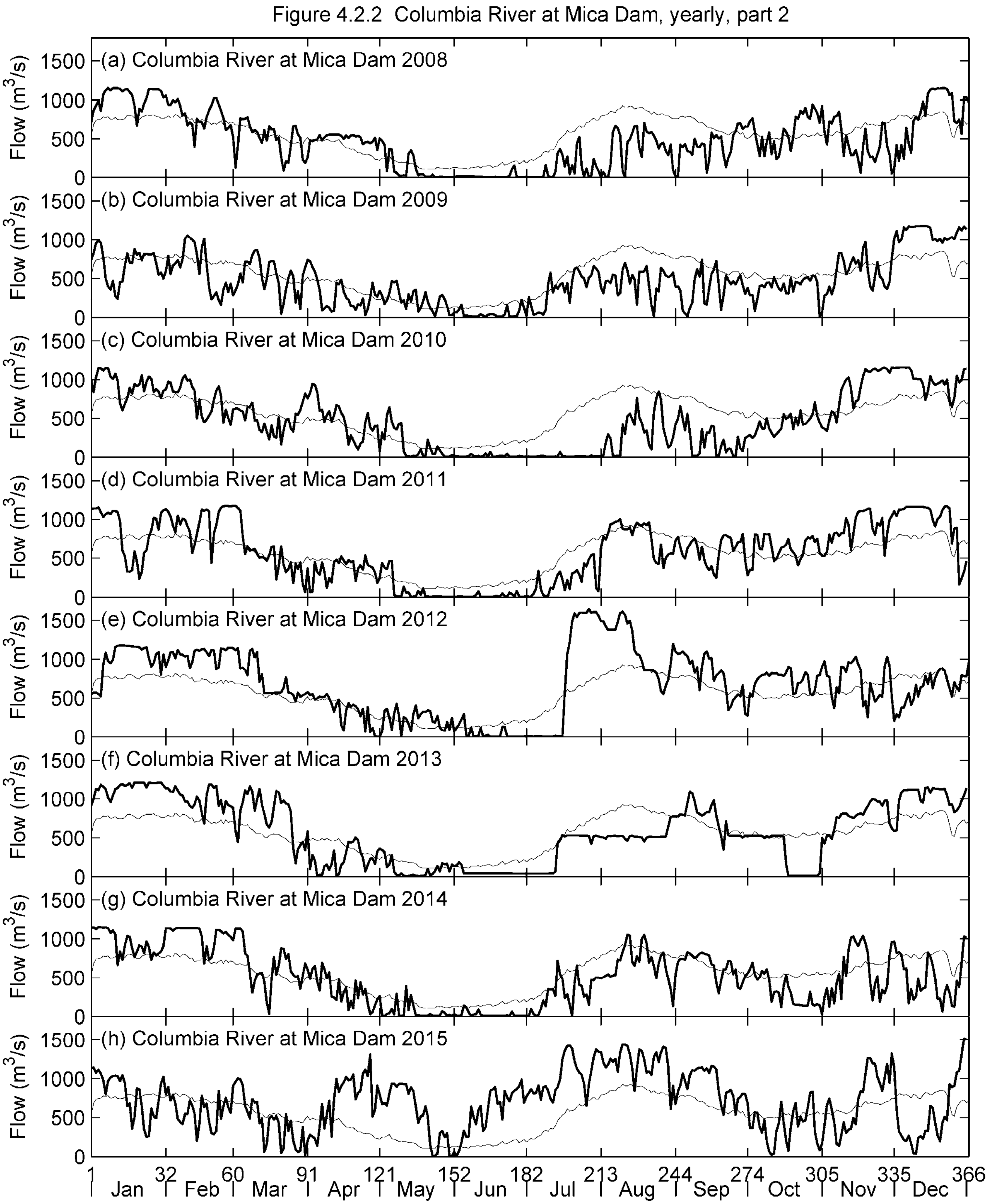


Figure 4.2.2. BC Hydro station "Columbia River at Mica Dam Outflow", selected years (heavy line). Mean flow for 1976-2013 (light line) is shown for comparison.

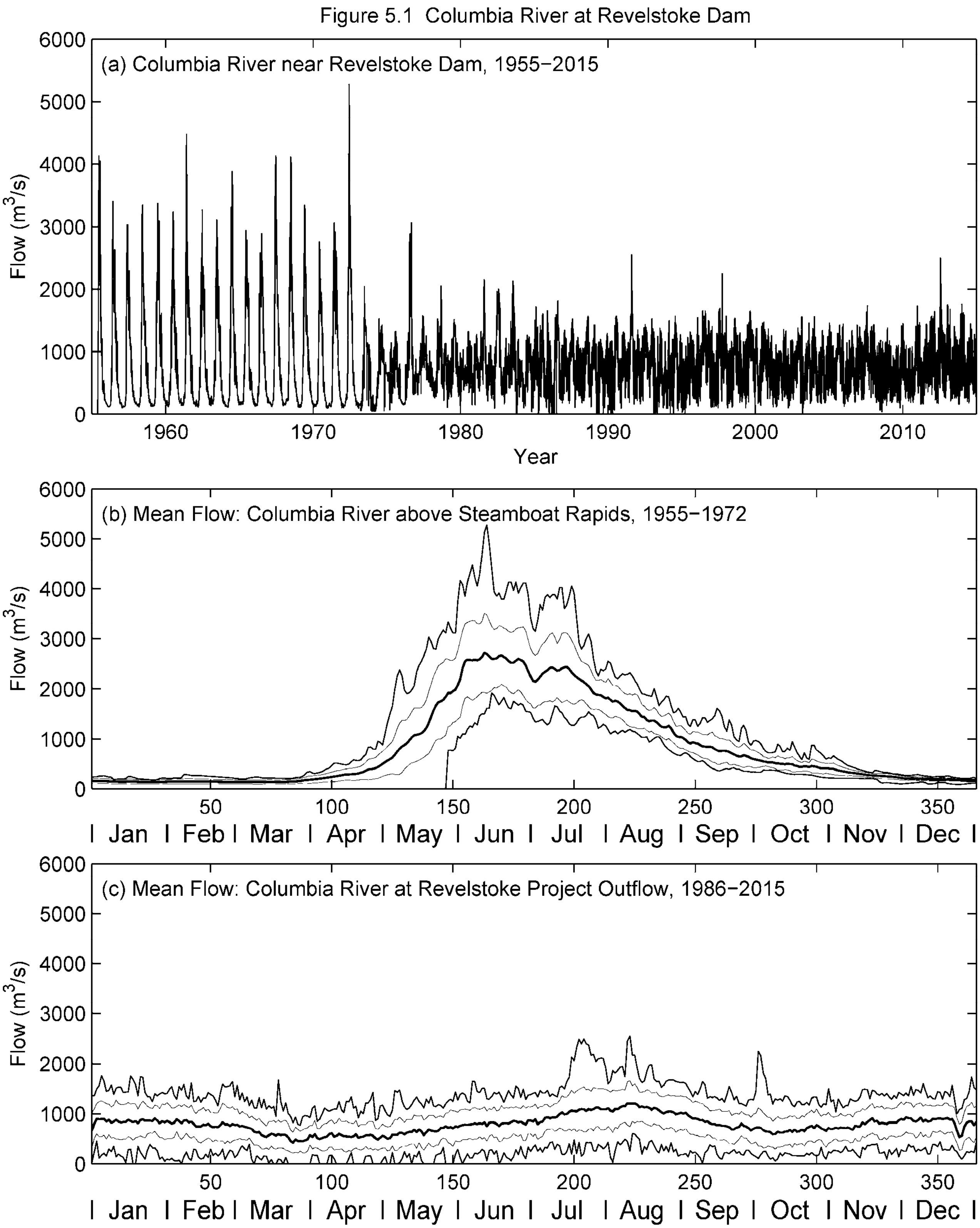


Figure 5.1. **(a)** WSC station 08ND011, "Columbia River above Steamboat Rapids", 1955-1985 and WSC station 08ND025, "Revelstoke Project Outflow", 1986-2013. **(b)** Mean pre-impoundment flow for the years indicated. **(c)** Mean post-impoundment flow for the years indicated. Mean (heavy line), maximum and minimum (medium lines) and mean ± one standard deviation (light lines).

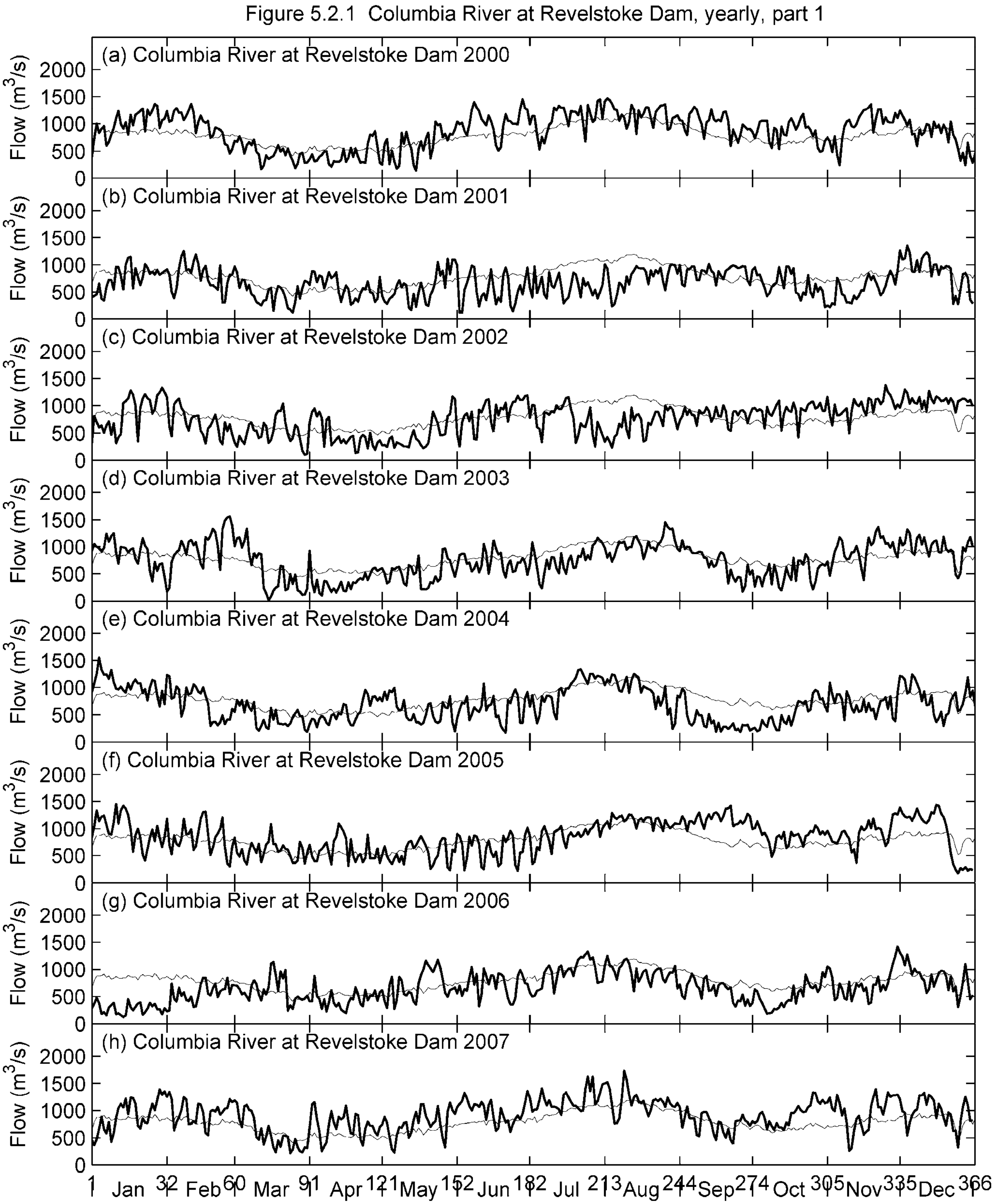


Figure 5.2.1. WSC station 08ND025, "Revelstoke Project Outflow", selected years (heavy line). Mean flow for 1986-2013 (light line) is shown for comparison.

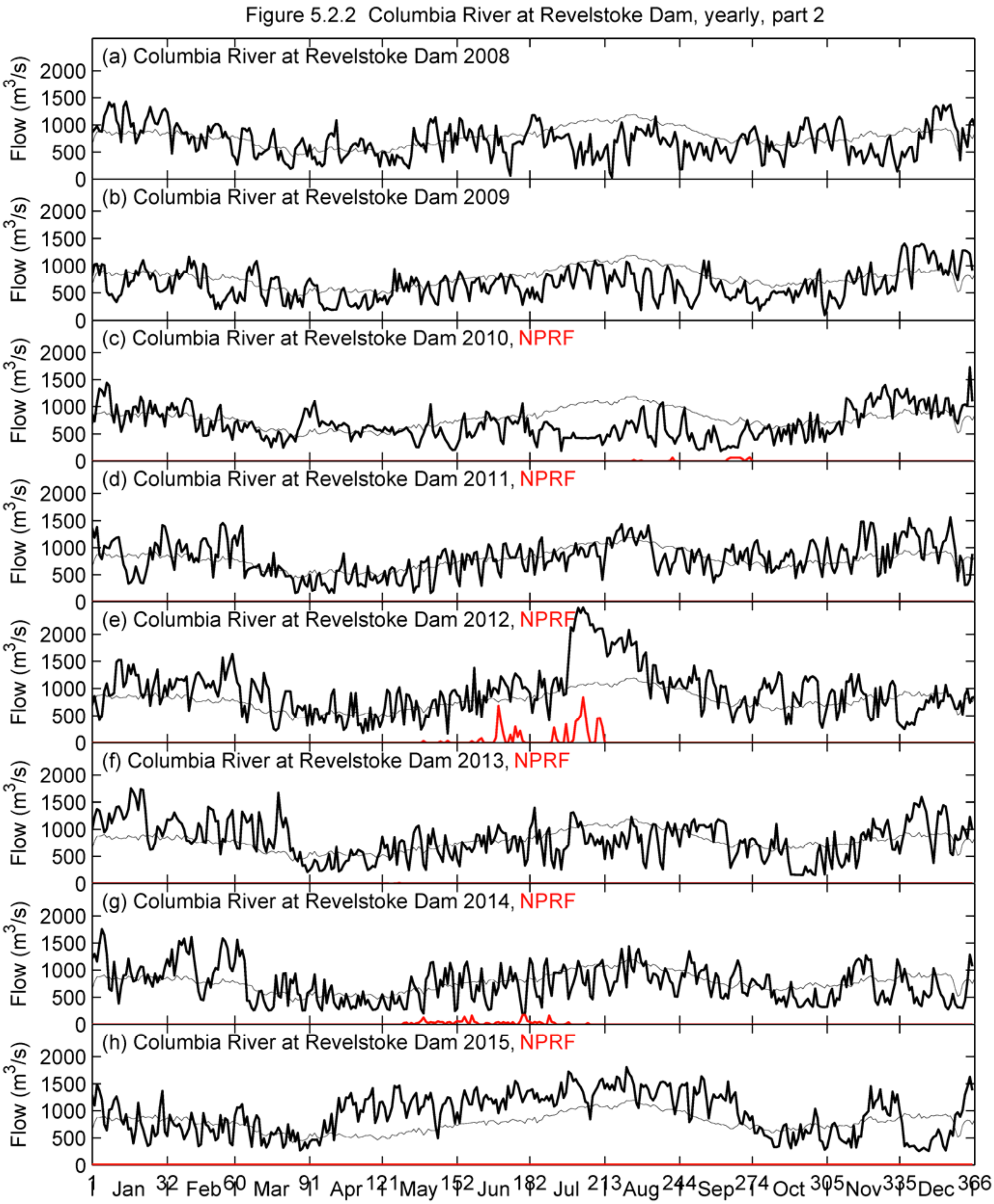


Figure 5.2.2. WSC station 08ND025, "Revelstoke Project Outflow", selected years (heavy line). Mean flow for 1986-2013 (light line) is shown for comparison. NPRF (RED) marks non-power flow (spill).

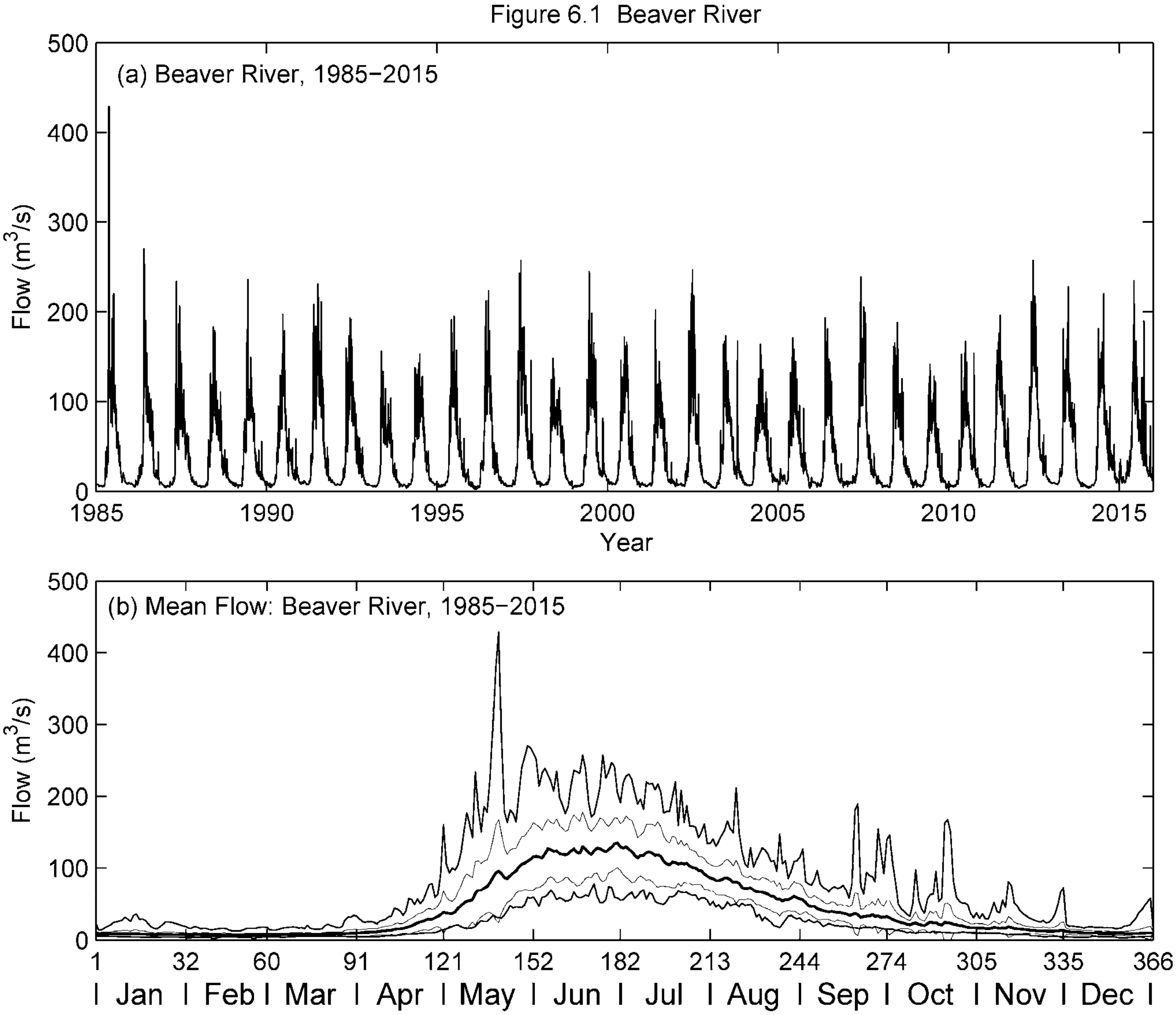


Figure 6.1. **(a)** WSC station 08NB019, “'Beaver River near the Mouth”, 1985-2013. **(b)** Mean flow for the years indicated. Mean (heavy line), maximum and minimum (medium lines) and mean ± one standard deviation (light lines).

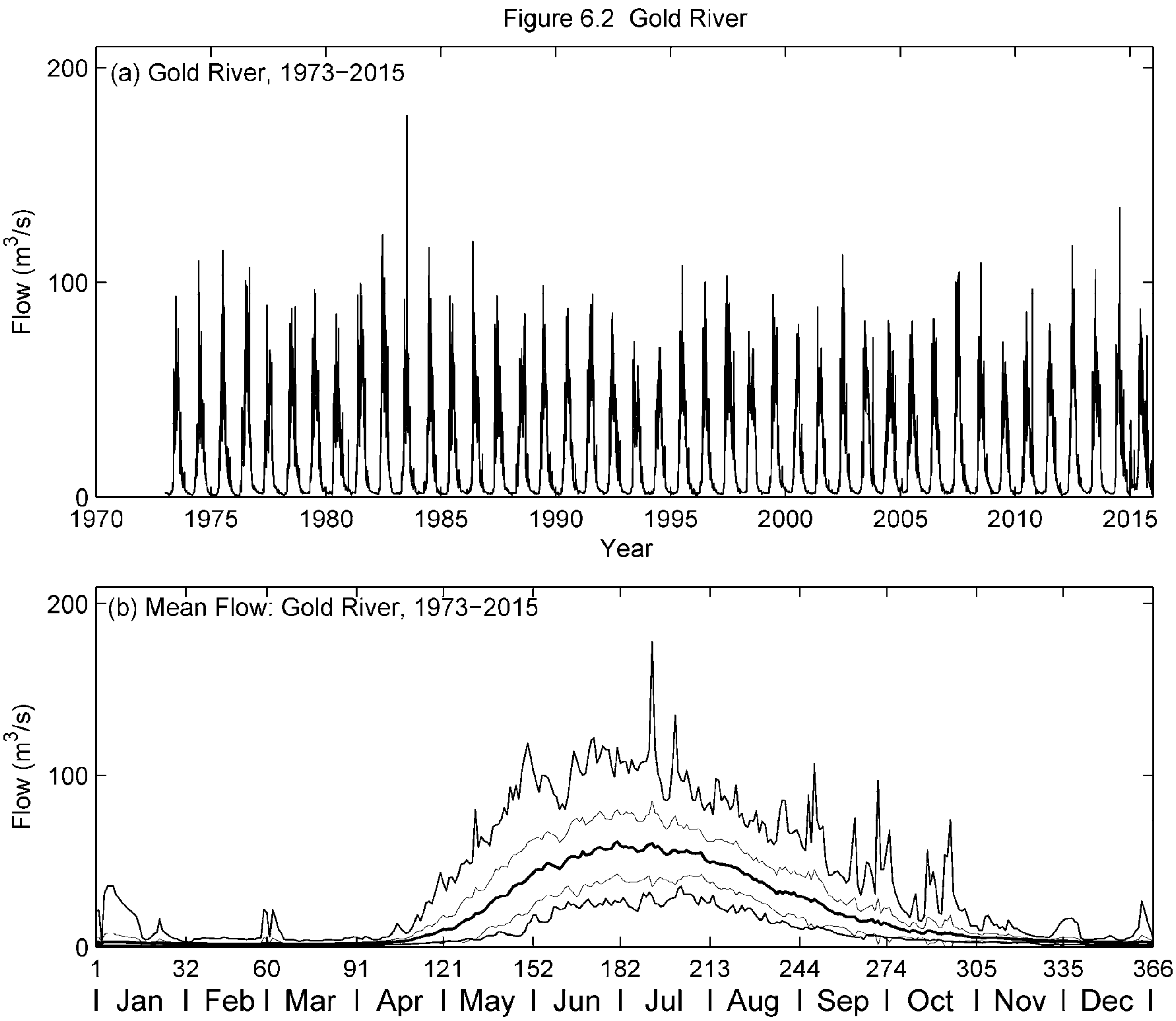


Figure 6.2. (a) WSC station 08NB014, "Gold River above Palmer Creek", 1973-2013. **(b)** Mean flow for the years indicated. Mean (heavy line), maximum and minimum (medium lines) and mean ± one standard deviation (light lines).

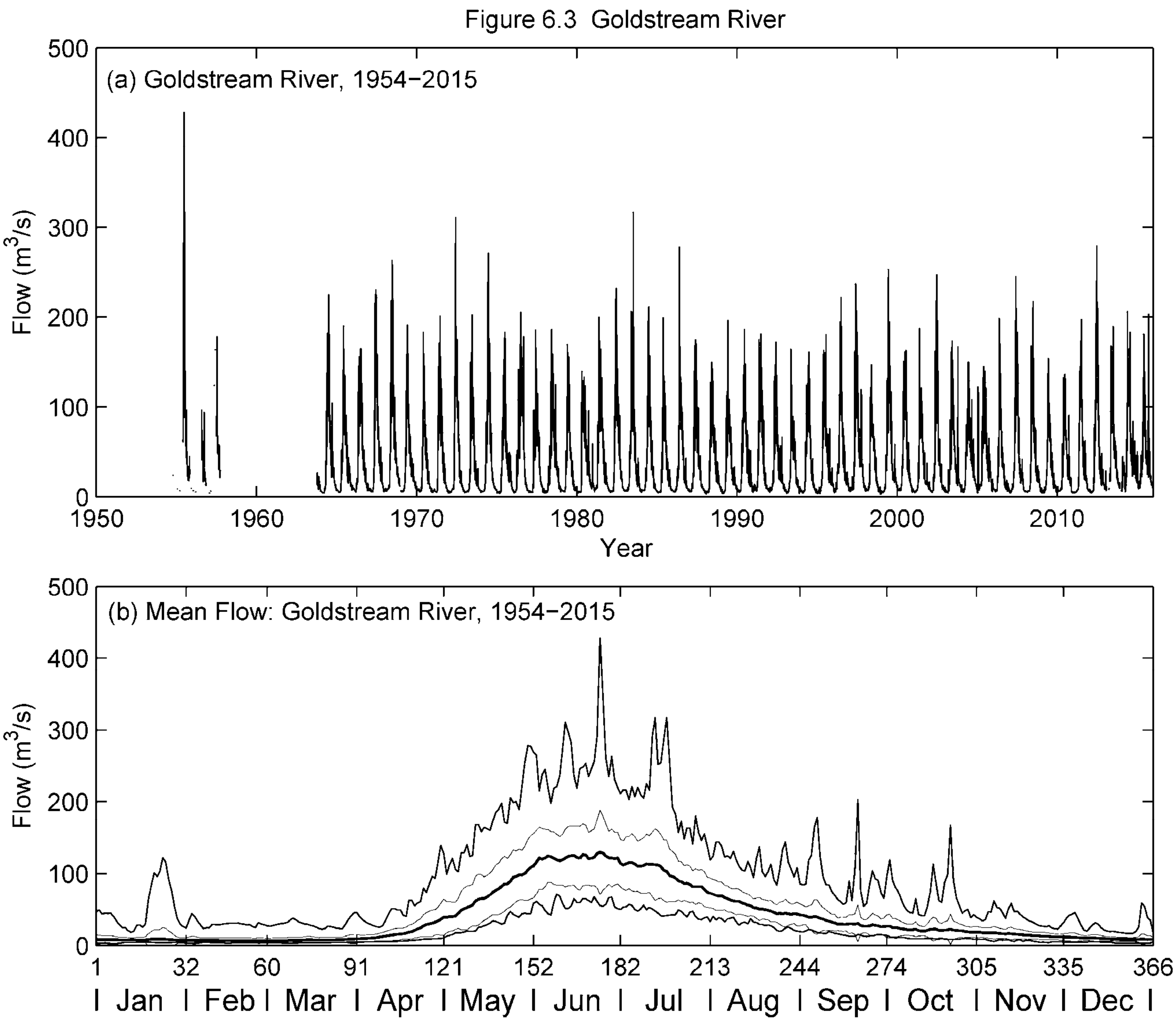


Figure 6.3. (a) WSC station 08ND012, "Goldstream River below Old Camp Creek", 1954-2013. **(b)** Mean flow for the years indicated. Mean (heavy line), maximum and minimum (medium lines) and mean ± one standard deviation (light lines).

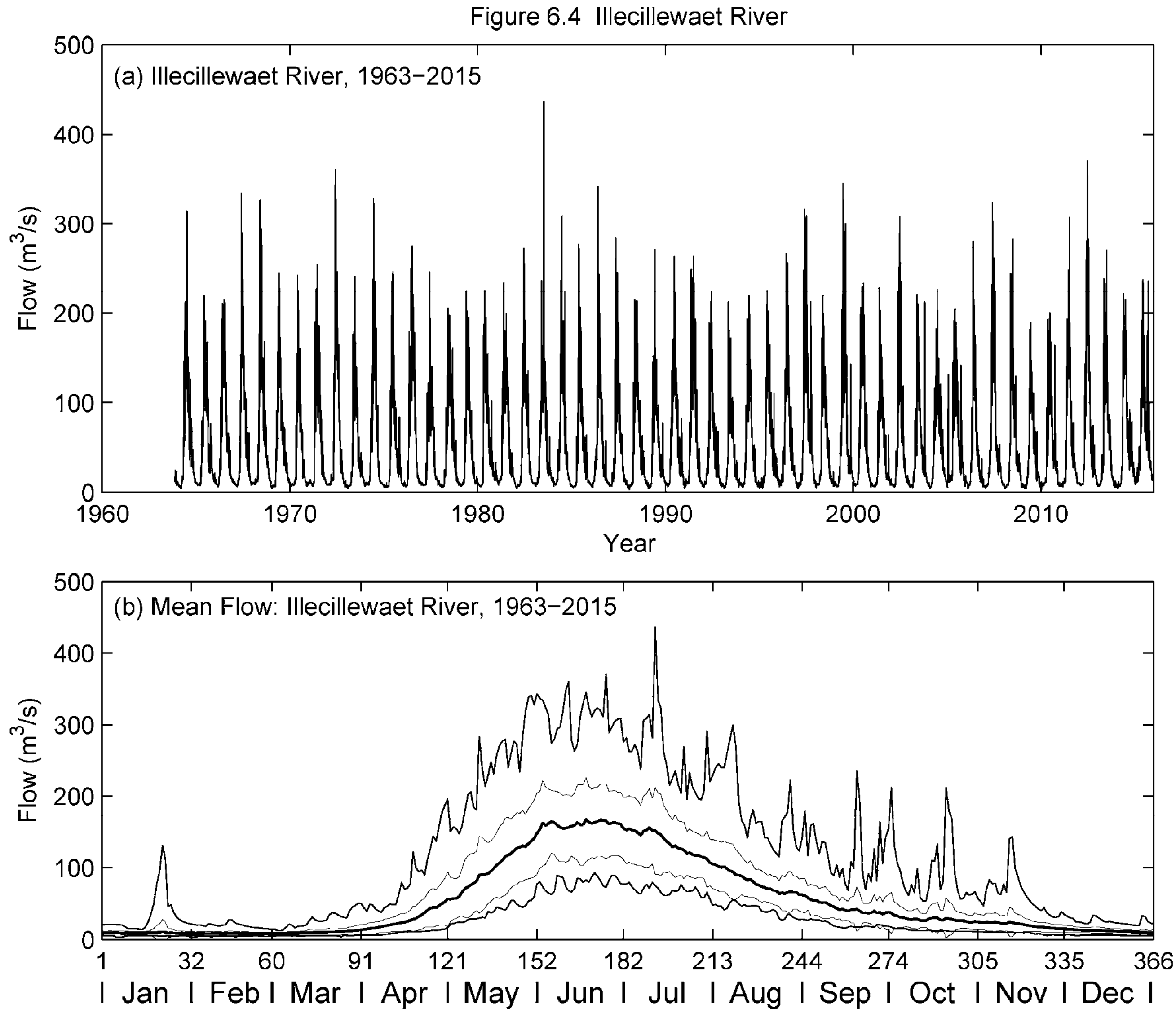


Figure 6.4. **(a)** WSC station 08ND013, "Illecillewaet River at Greeley", 1963-2013. **(b)** Mean flow for the years indicated. Mean (heavy line), maximum and minimum (medium lines) and mean ± one standard deviation (light lines).

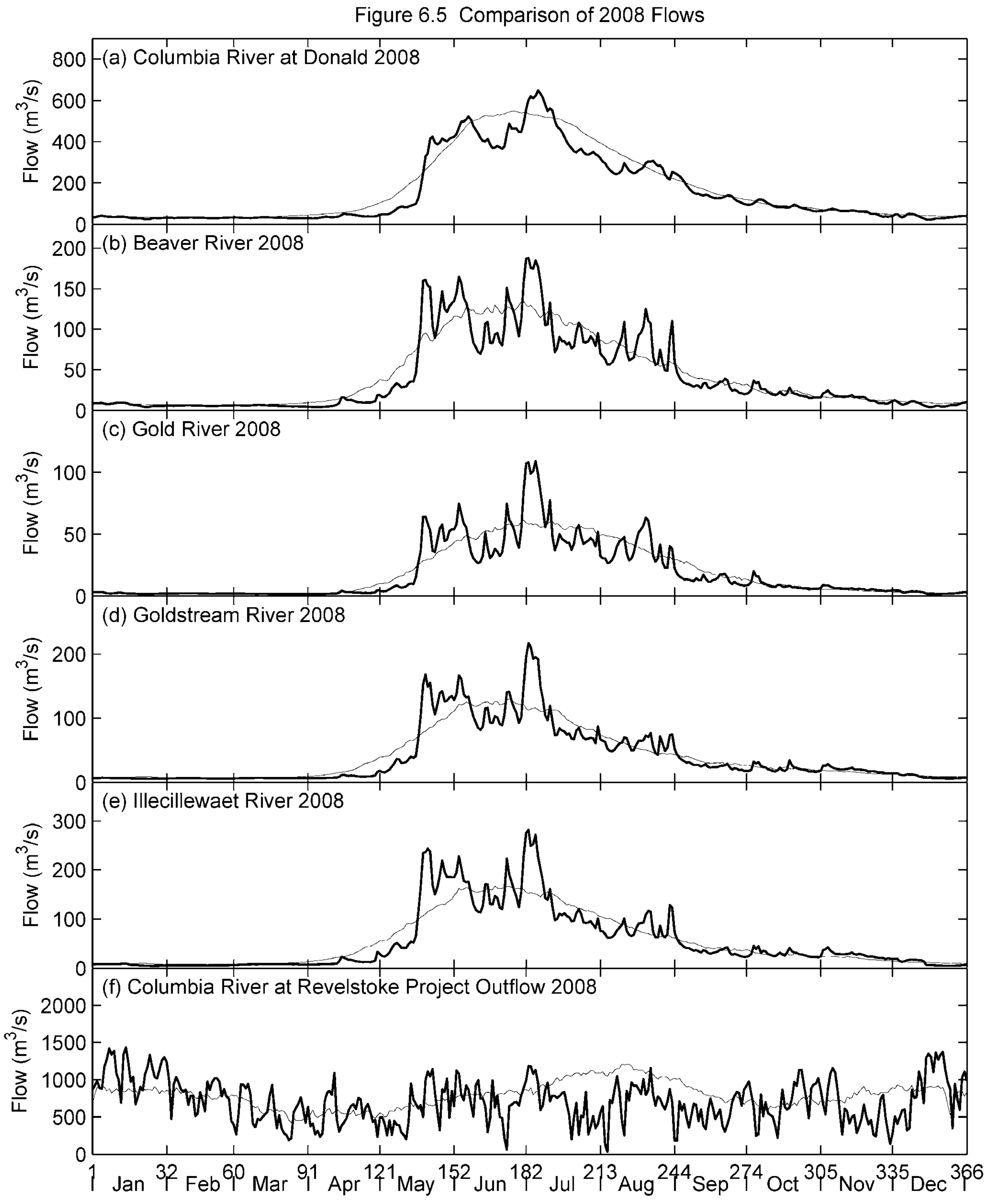


Figure 6.5. Comparison of flows in 2008 for the stations indicated (heavy line). Mean flows for a**)** 1944-2013 **b)** 1985-2013 **c)** 1973-2013 **d)** 1954-2013 **e)** 1963-2013 **f**) 1986-2013 (light line).

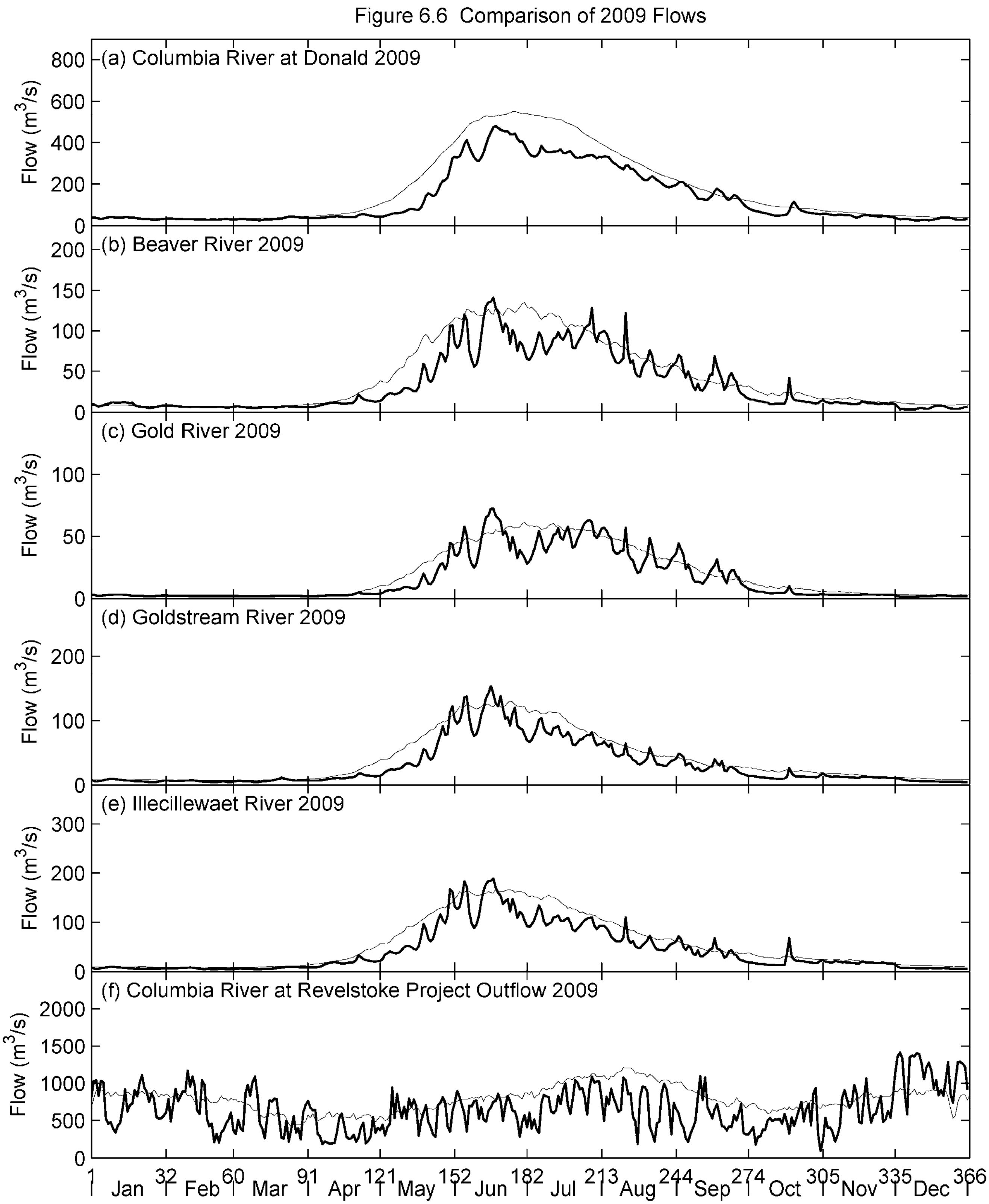


Figure 6.6. Comparison of flows in 2009 for the stations indicated (heavy line). Mean flows for **a)** 1944-2013 **b)** 1985-2013 **c)** 1973-2013 **d)** 1954-2013 **e)** 1963-2013 **f**) 1986-2013 (light line).

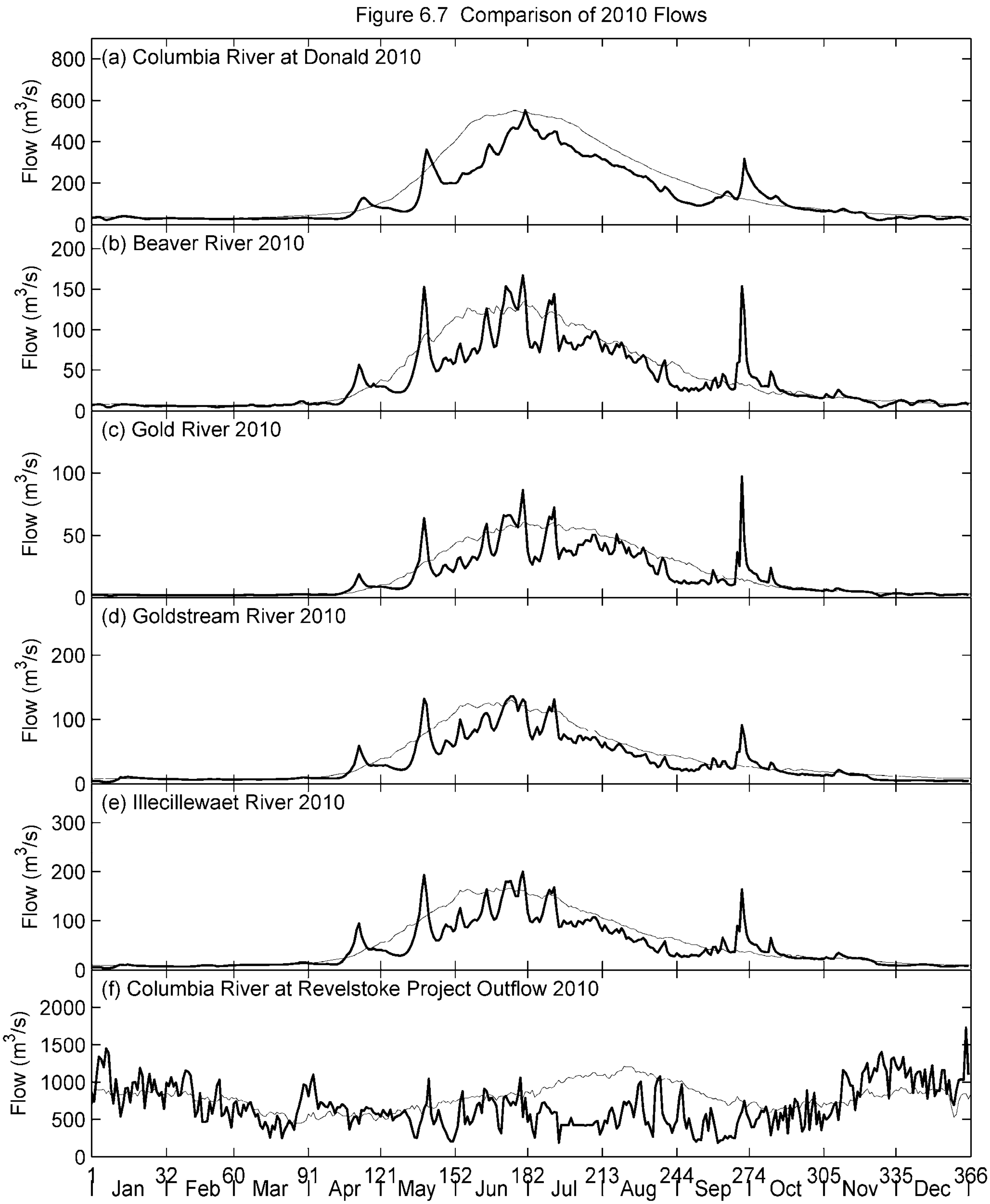


Figure 6.7. Comparison of flows in 2010 for the stations indicated (heavy line). Mean flows for **a)** 1944-2013 **b)** 1985-2013 **c)** 1973-2013 **d)** 1954-2013 **e)** 1963-2013 **f**) 1986-2013 (light line).

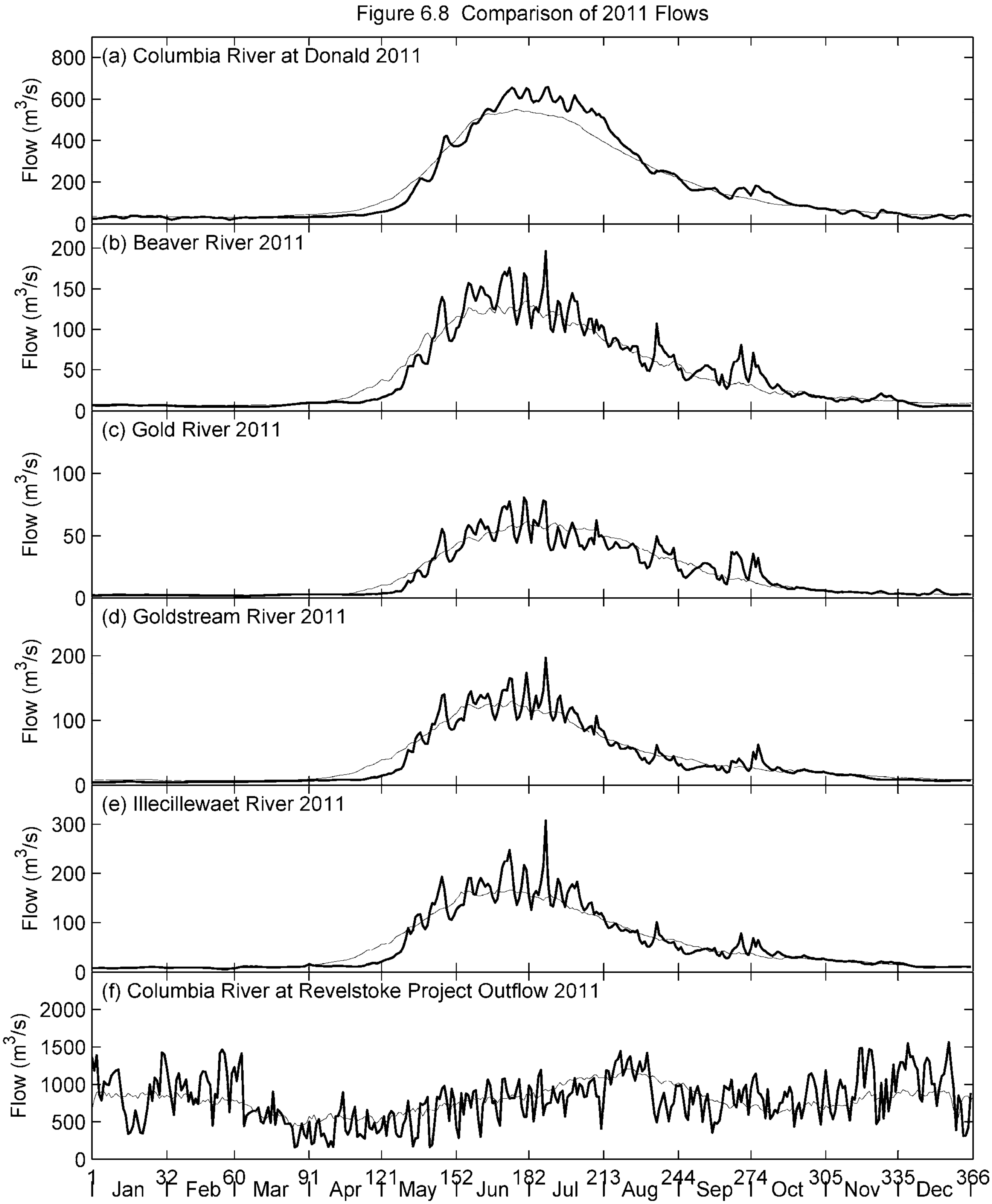


Figure 6.8. Comparison of flows in 2011 for the stations indicated (heavy line). Mean flows for **a)** 1944-2013 **b)** 1985-2013 **c)** 1973-2013 **d)** 1954-2013 **e)** 1963-2013 **f)** 1986-2013 (light line).

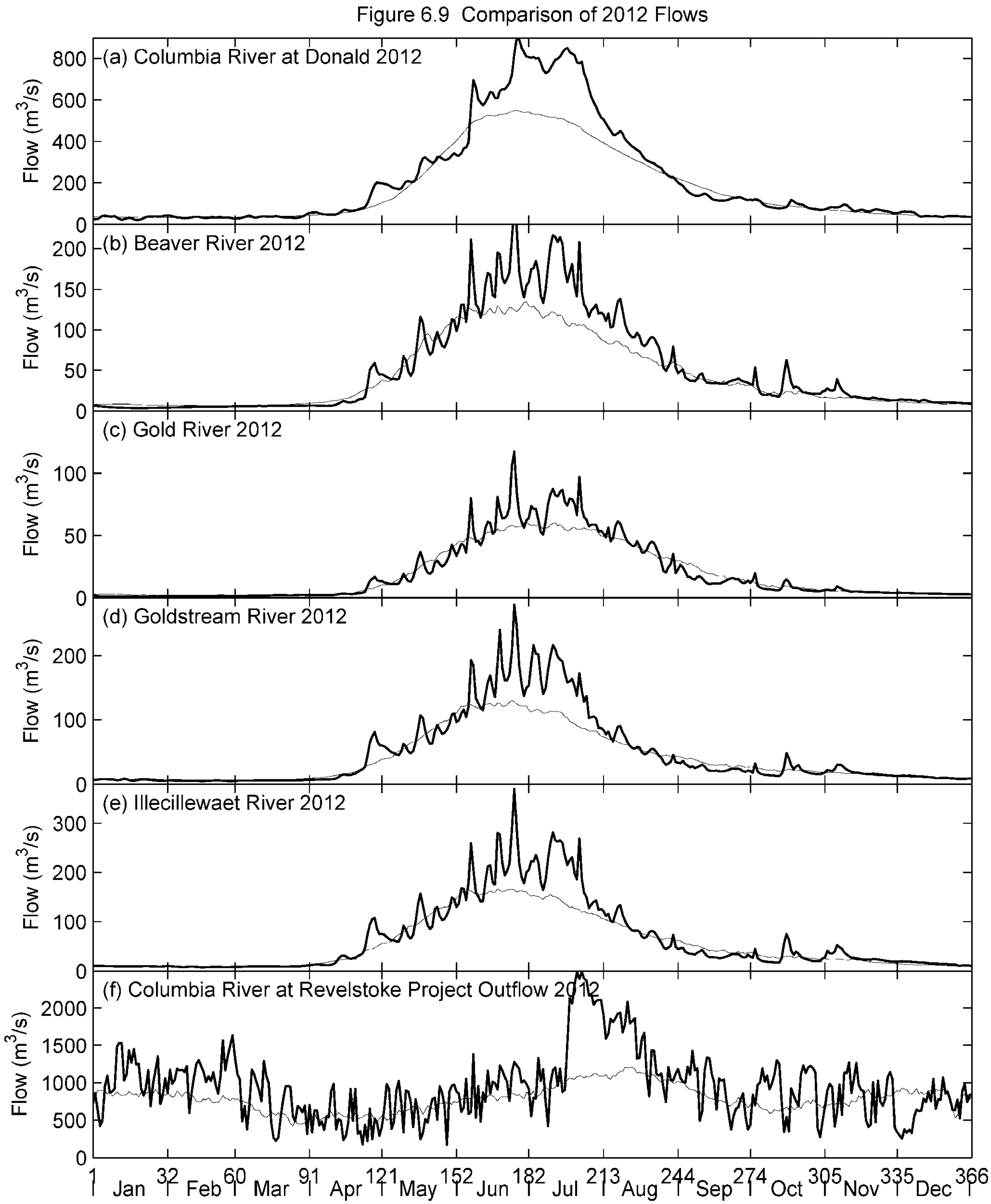


Figure 6.9. Comparison of flows in 2012 for the stations indicated (heavy line). Mean flows for **a)** 1944-2012 **b)** 1985-2012 **c)** 1973-2012 **d)** 1954-2012 **e)** 1963-2012 **f**) 1986-2012 (light line).

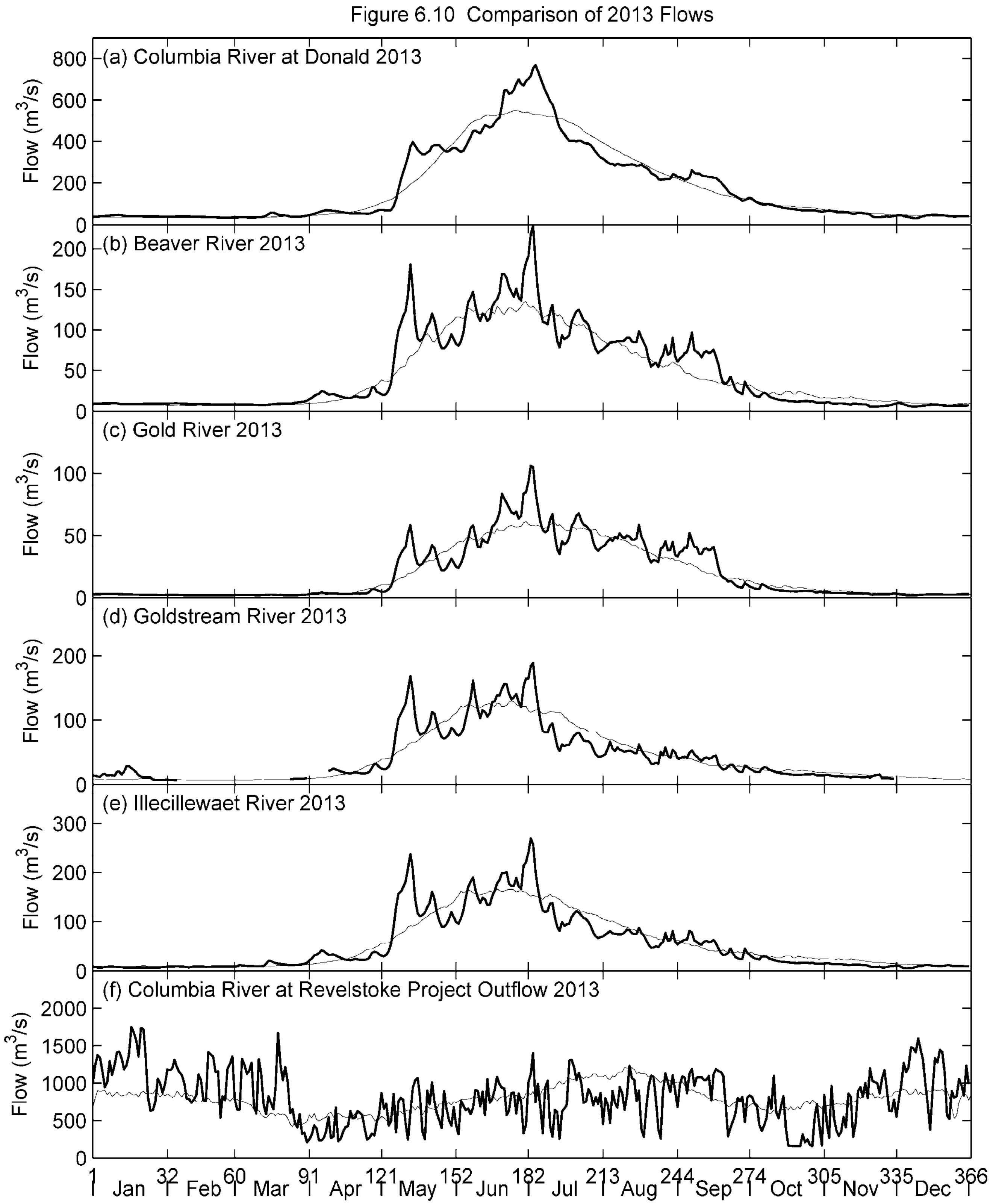


Figure 6.10. Comparison of flows in 2013 for the stations indicated (heavy line). Mean flows for **a)** 1944-2013 **b)** 1985-2013 **c)** 1973-2013 **d)** 1954-2013 **e)** 1963-2013 **f)** 1986-2013 (light line).

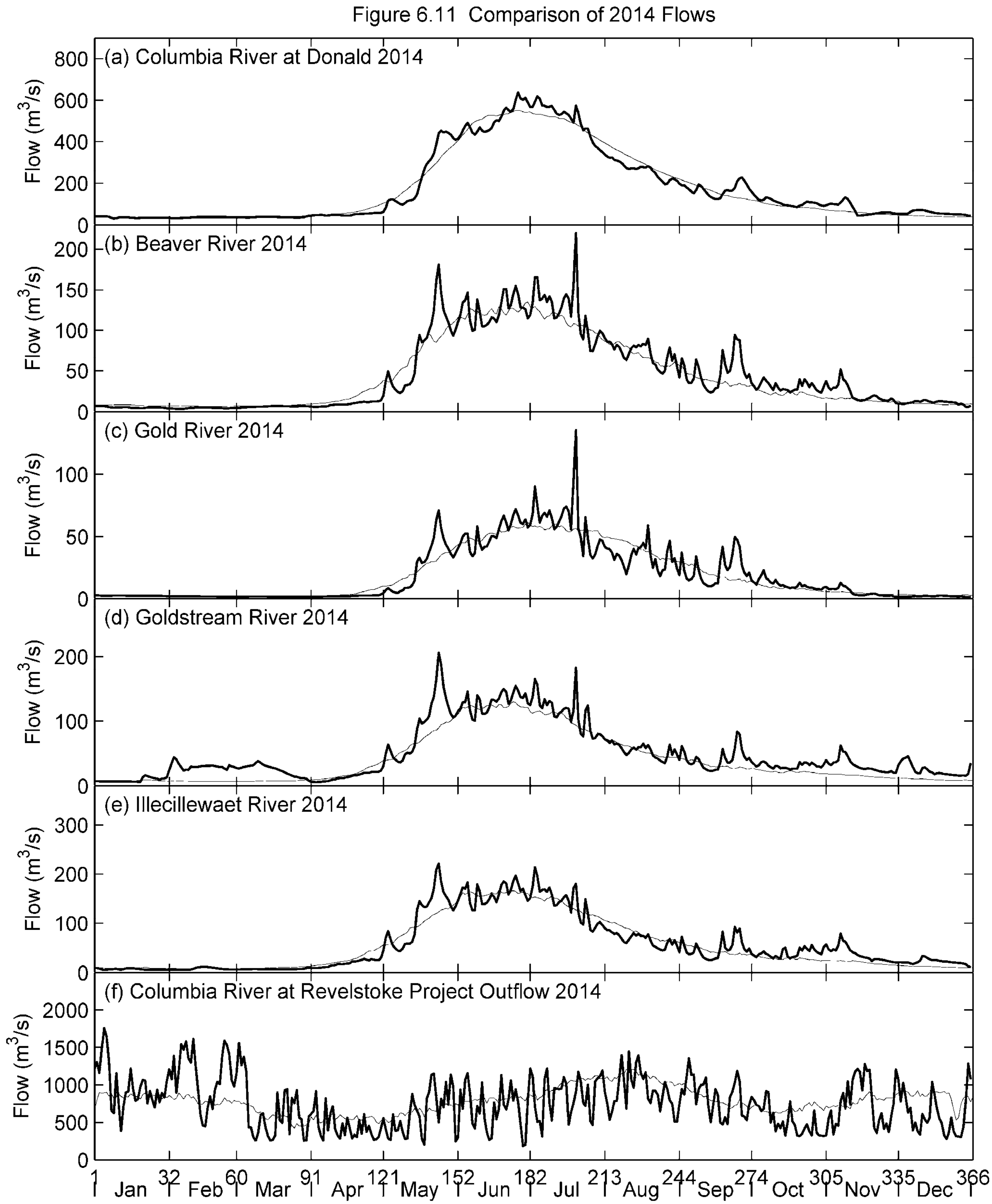


Figure 6.11. Comparison of flows in 2014 for the stations indicated (heavy line). Mean flows for **a)** 1944-2013 **b)** 1985-2013 **c)** 1973-2013 **d)** 1954-2013 **e)** 1963-2013 **f**) 1986-2013 (light line).

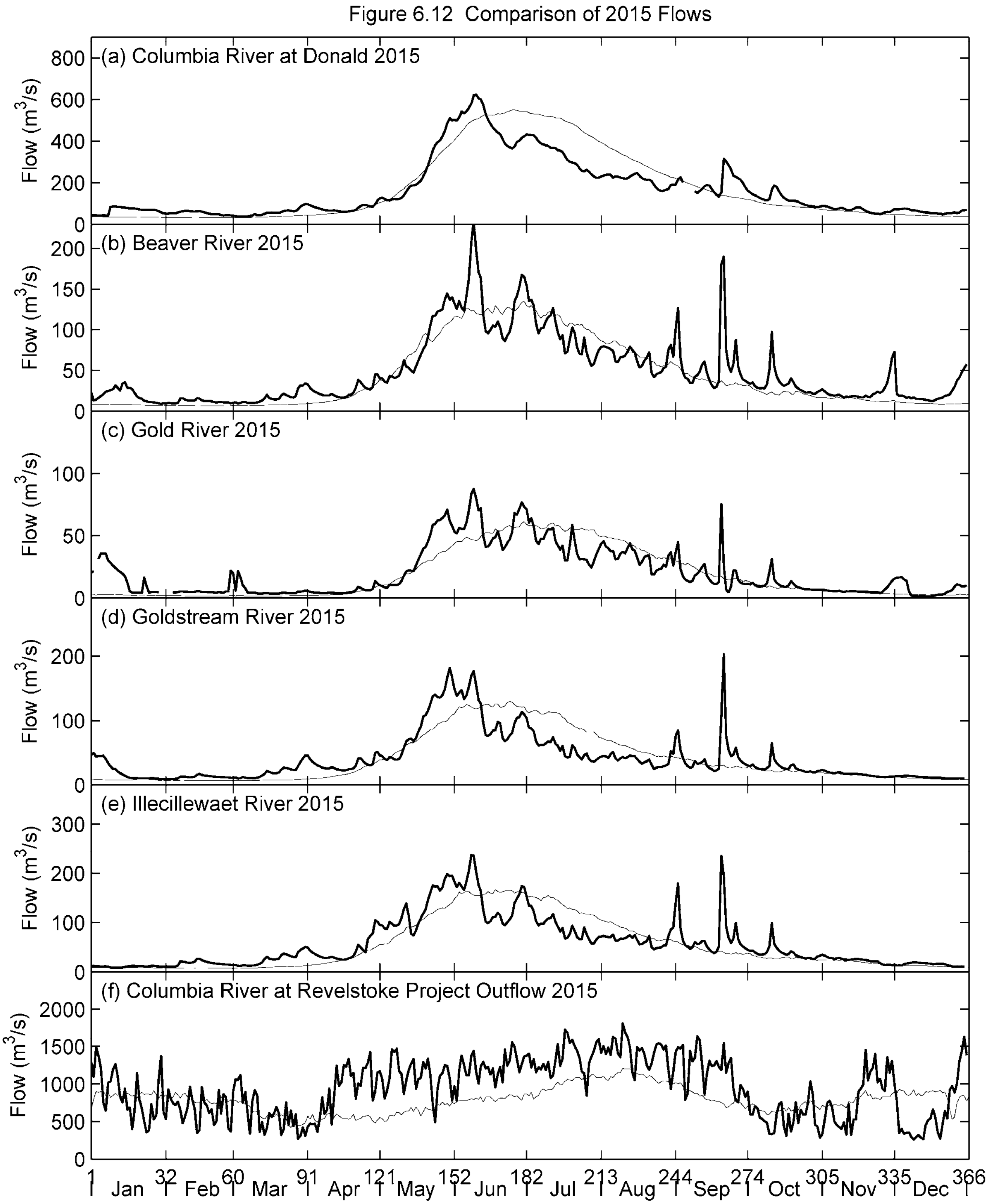


Figure 6.12. Comparison of flows in 2015 for the stations indicated (heavy line). Mean flows for **a)** 1944-2013 **b)** 1985-2013 **c)** 1973-2013 **d)** 1954-2013 **e)** 1963-2013 **f**) 1986-2013 (light line).

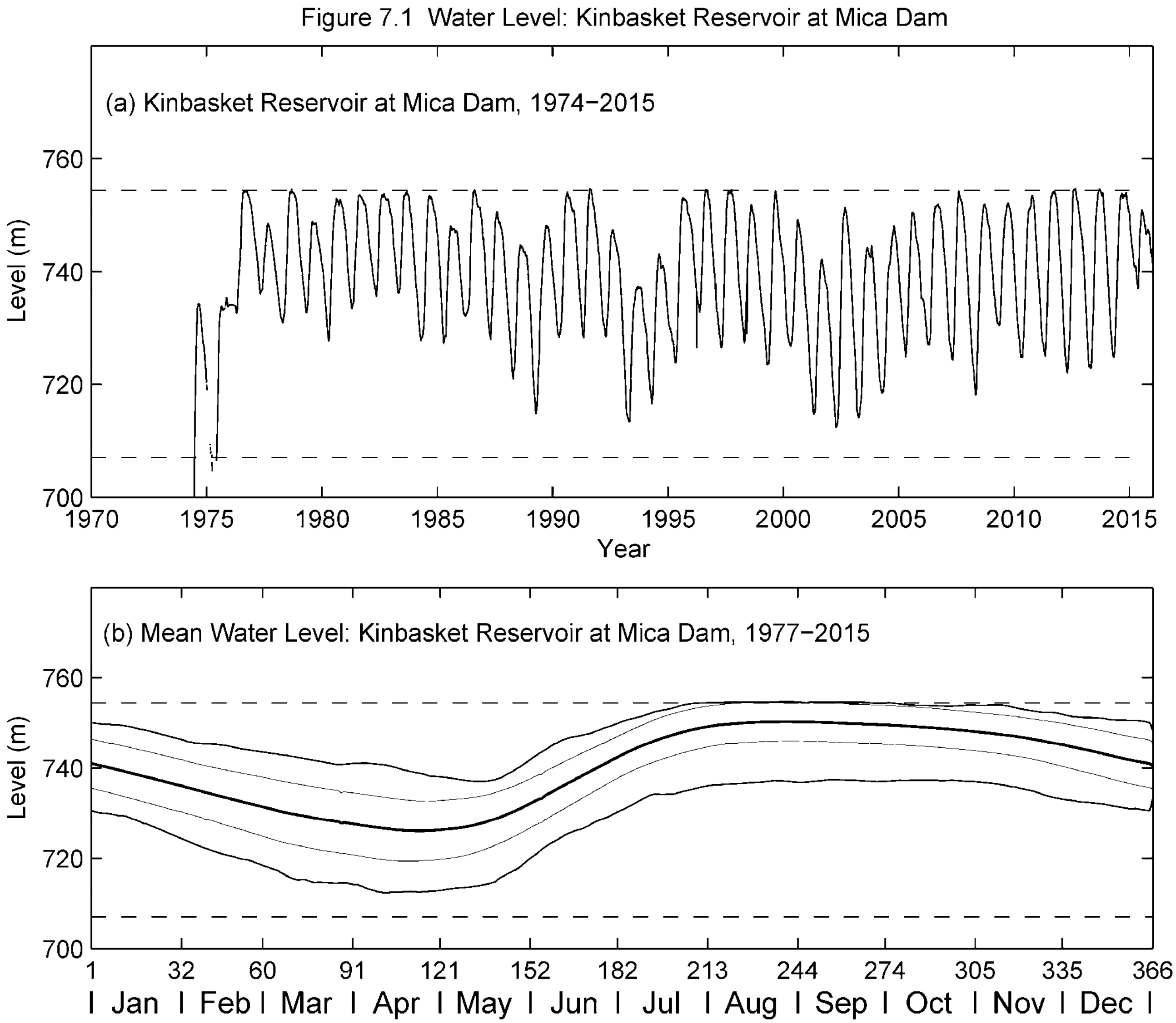


Figure 7.1. **(a)** WSC station 08ND017 “Kinbasket Lake at Mica Dam”, 1974-2013. **(b)** Mean daily water level for 1977-2013. Mean (heavy line), maximum and minimum (medium lines) and mean ± one standard deviation (light lines). Dash lines mark the normal minimum and maximum elevation.

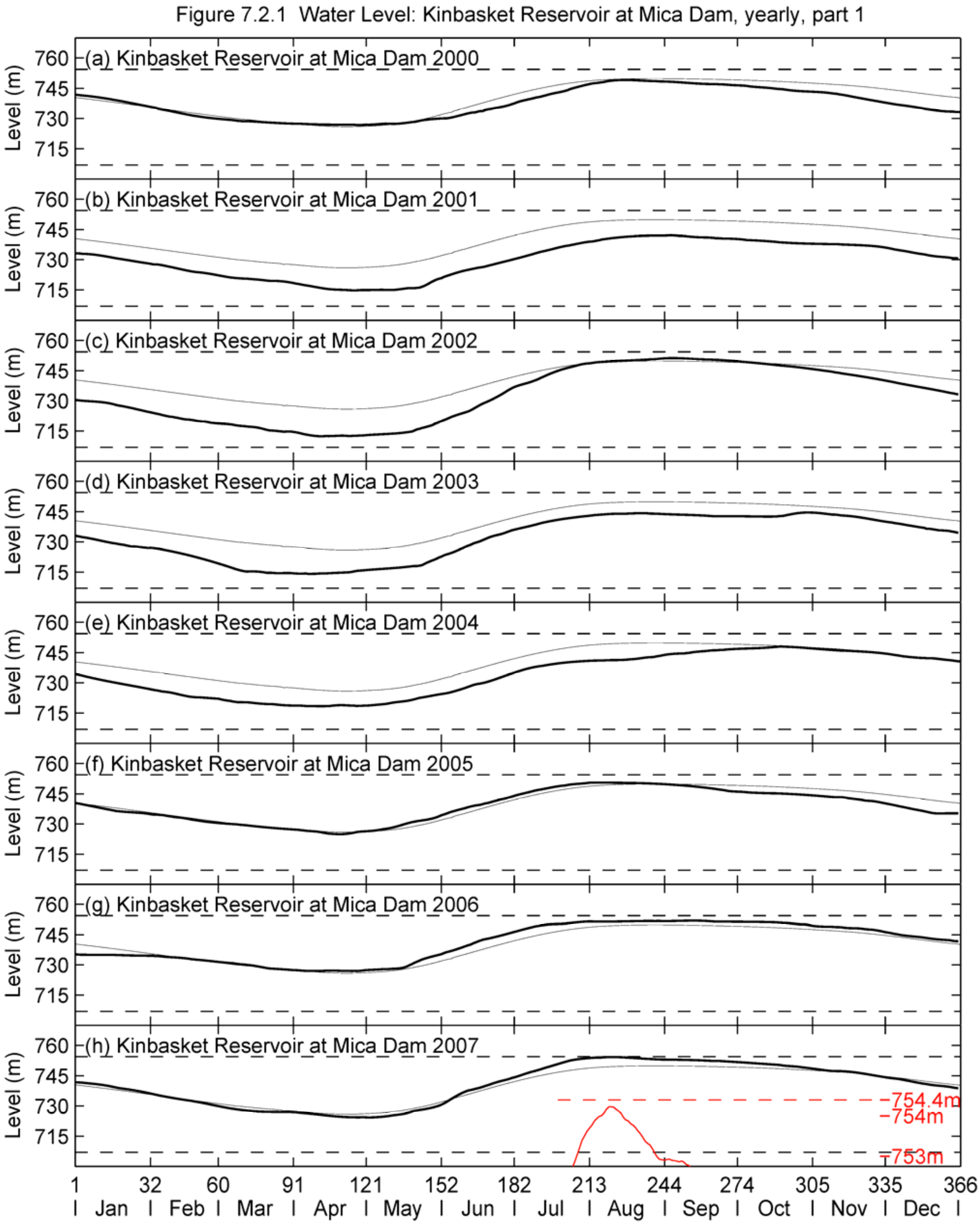


Figure 7.2.1. Water levels for WSC station 08ND017 "Kinbasket Lake at Mica Dam", selected years (heavy line). Mean daily water level for 1977-2013 (light line) is shown for comparison. Data for 2-30 April 2007 replaced with that from Kinbasket Lake below Garrett Creek. Dash lines mark the normal minimum and maximum elevation.

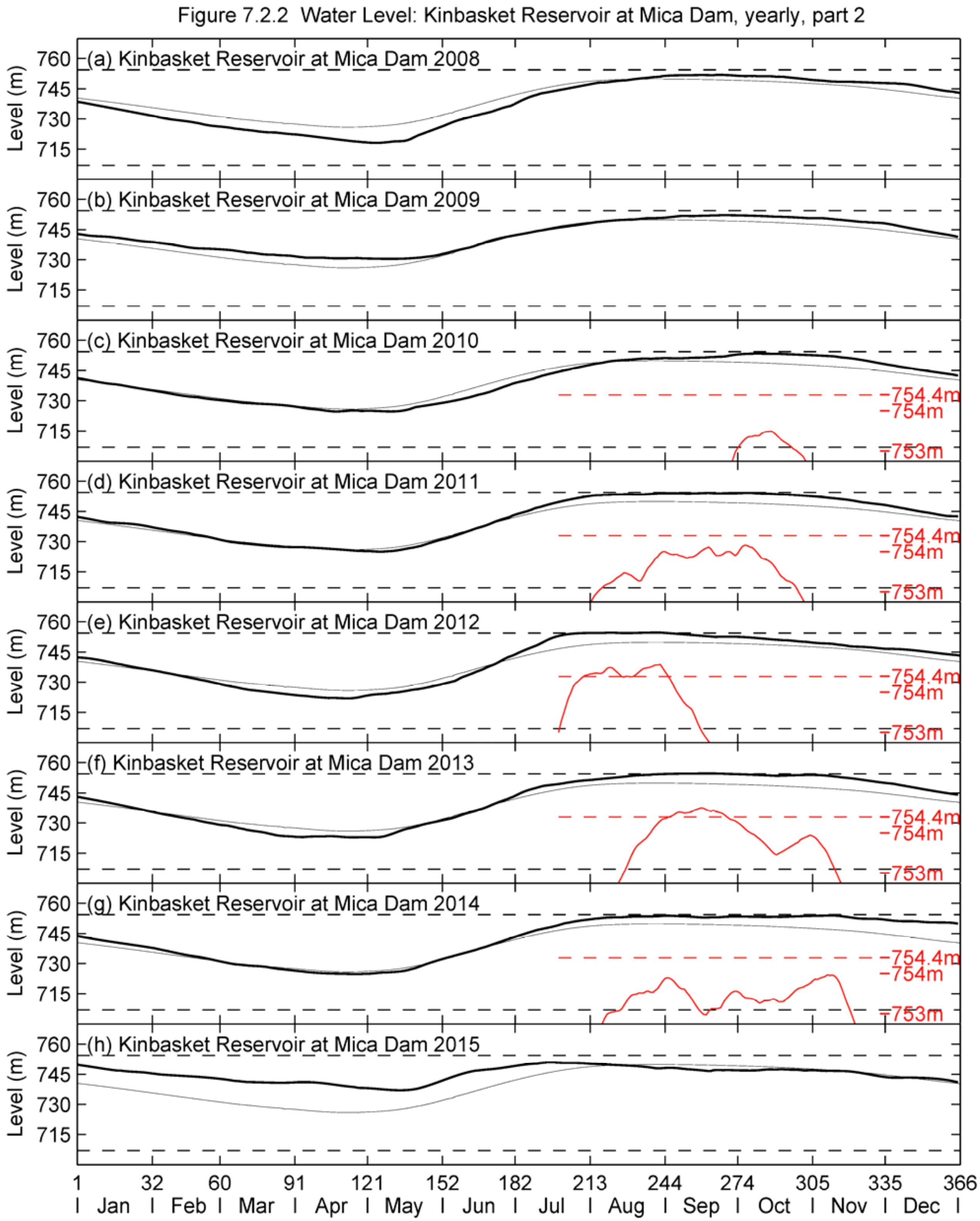


Figure 7.2.2. Water levels for WSC station 08ND017 "Kinbasket Lake at Mica Dam", selected years (heavy line). Mean daily water level for 1977-2013 (light line) is shown for comparison. Data for 2-30 April 2007 replaced with that from Kinbasket Lake below Garrett Creek. Dash lines mark the normal minimum and maximum elevation.

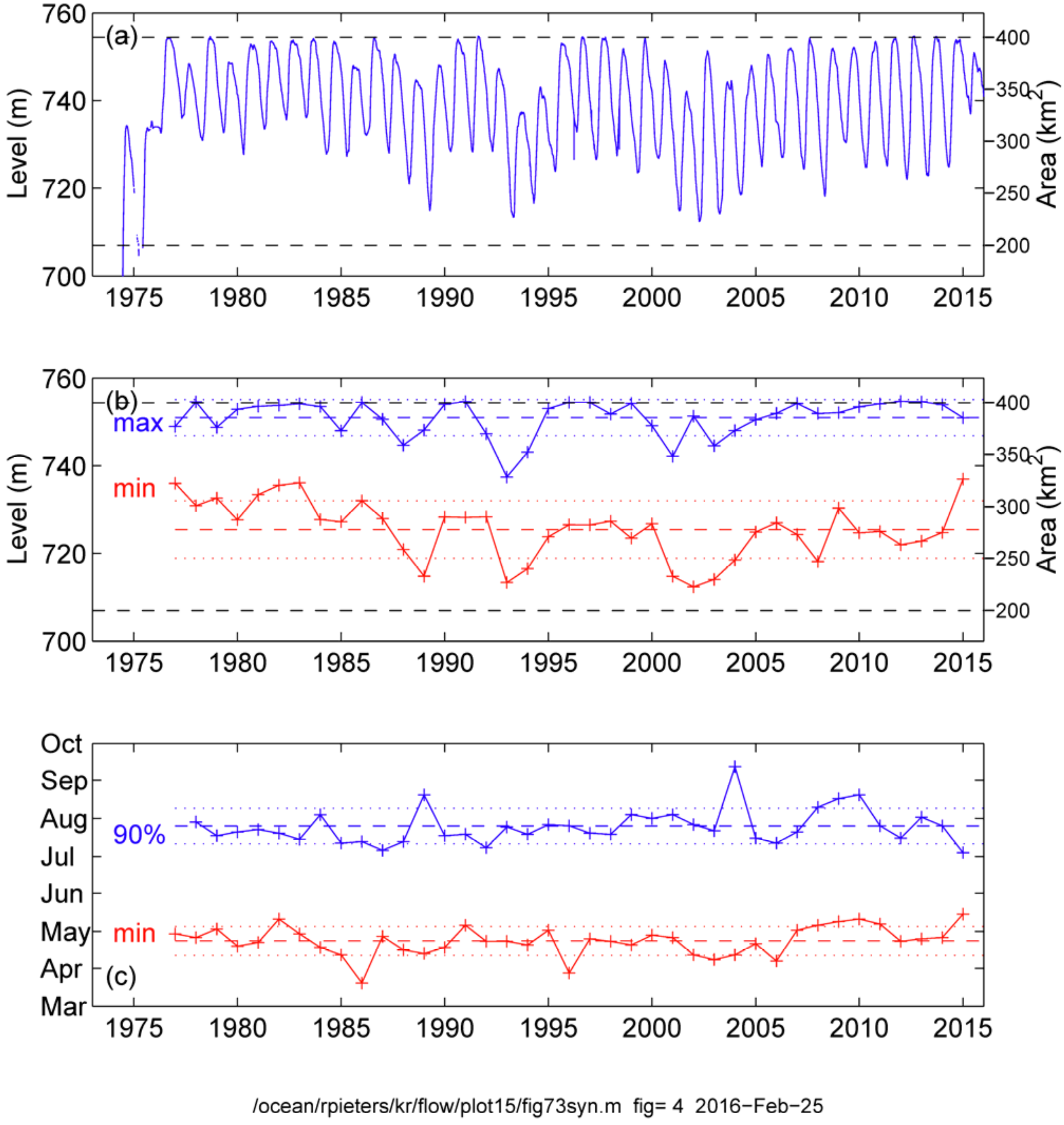


Figure 7.3 (a) Water level in Kinbasket Reservoir, 1973-2013. Black dash lines mark normal minimum and maximum water level. (b) Minimum (red) and maximum (blue) water level for 1977-2013. (c) Date of minimum (red), 90% maximum (blue) water level for 1977-2013. The time to 90% full is shown because the time to the maximum water level can occur later in some years. Red and blue dash lines mark the average, and dotted lines mark ± 1 standard deviation.

Figure 8.1 Water Level: Revelstoke Reservoir

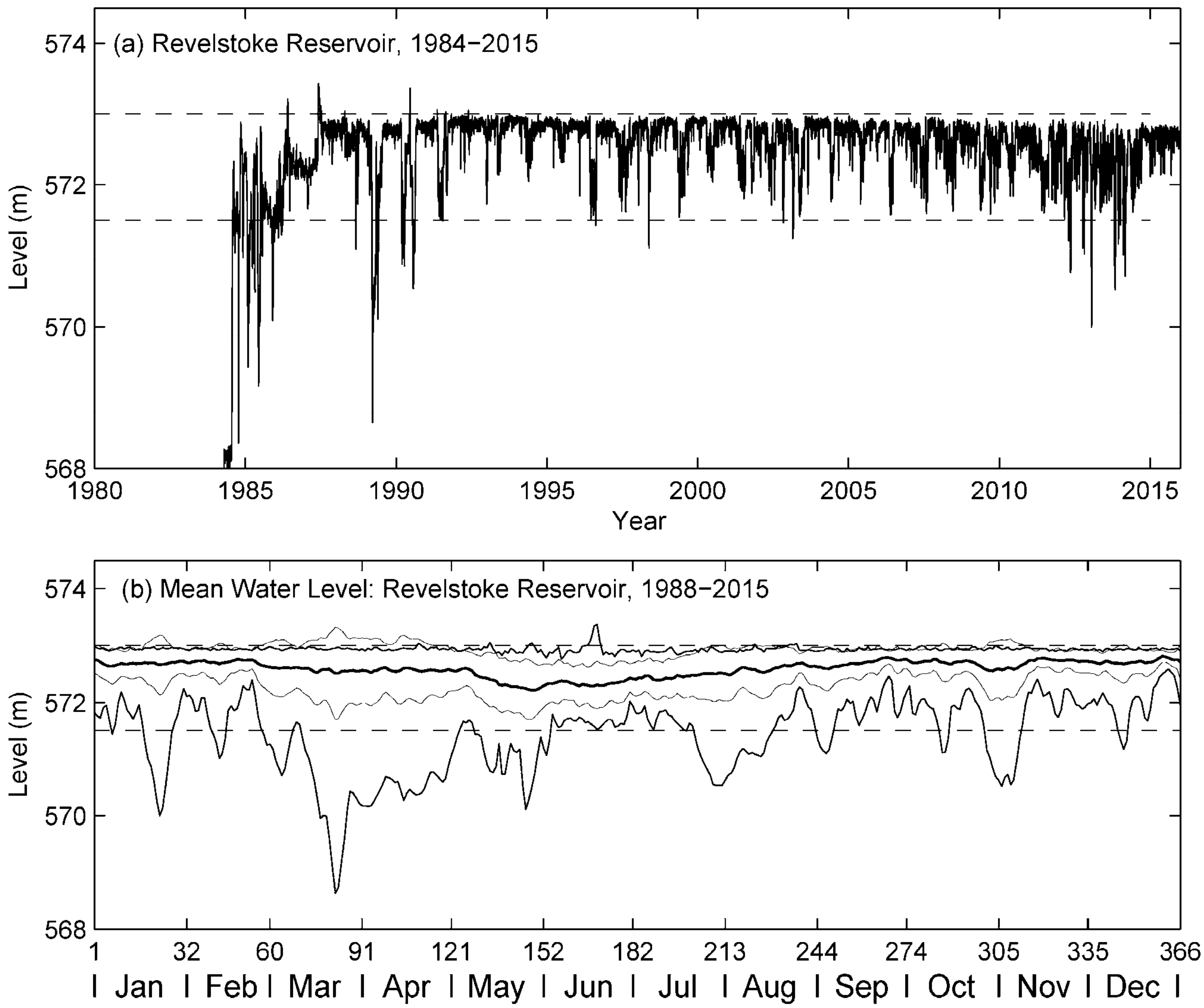


Figure 8.1. (a) BC Hydro station "Revelstoke Lake Forebay", 1984-2013. **(b)** Mean daily water level for 1988-2013. Mean (heavy line), maximum and minimum (medium lines) and mean ± one standard deviation (light lines). Dash lines mark the normal minimum and maximum elevation.

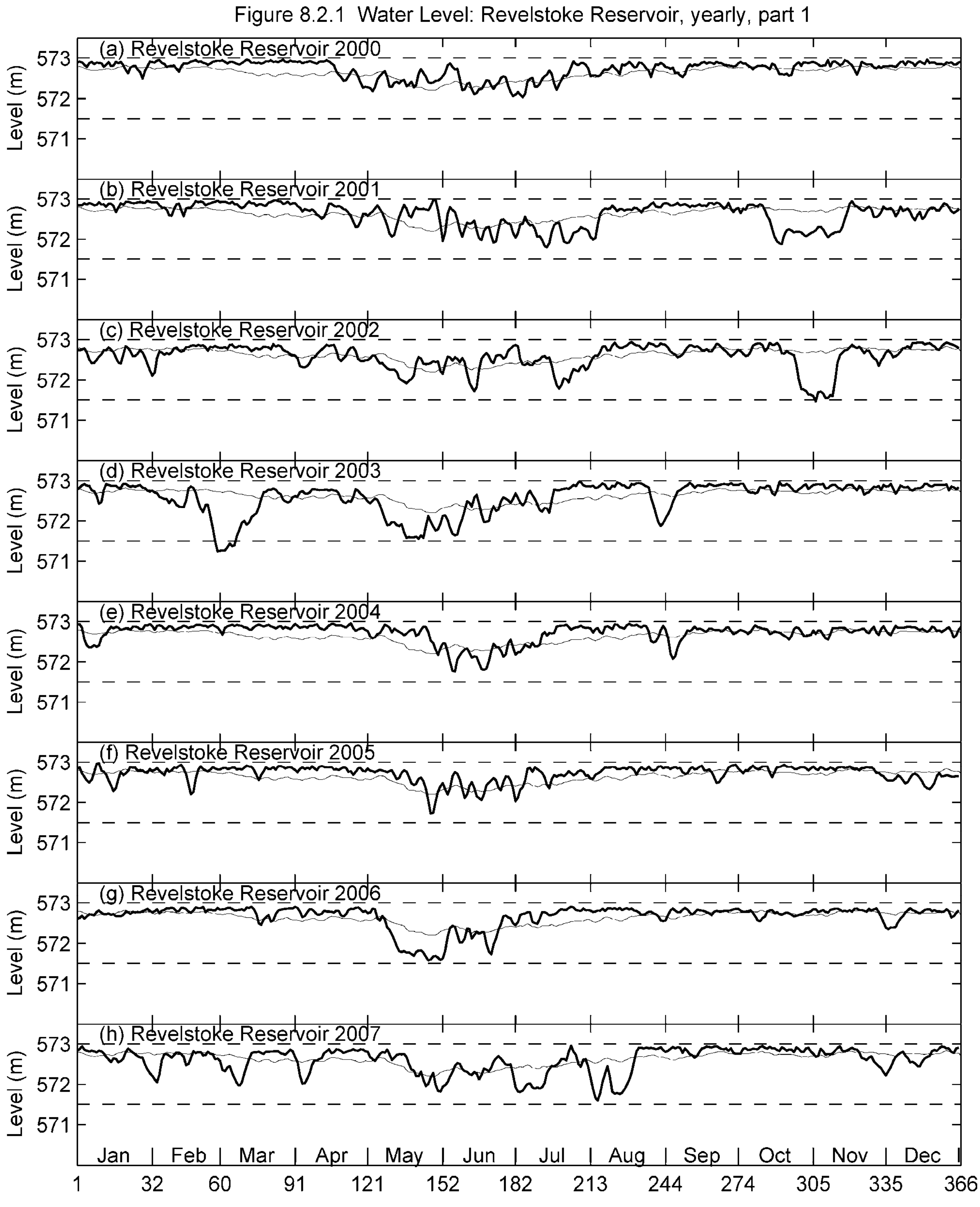


Figure 8.2.1. BC Hydro station "Revelstoke Lake Forebay", selected years (heavy line). Mean daily water level for 1988-2013 (light line) is shown for comparison. Dash lines mark the normal minimum and maximum elevation.

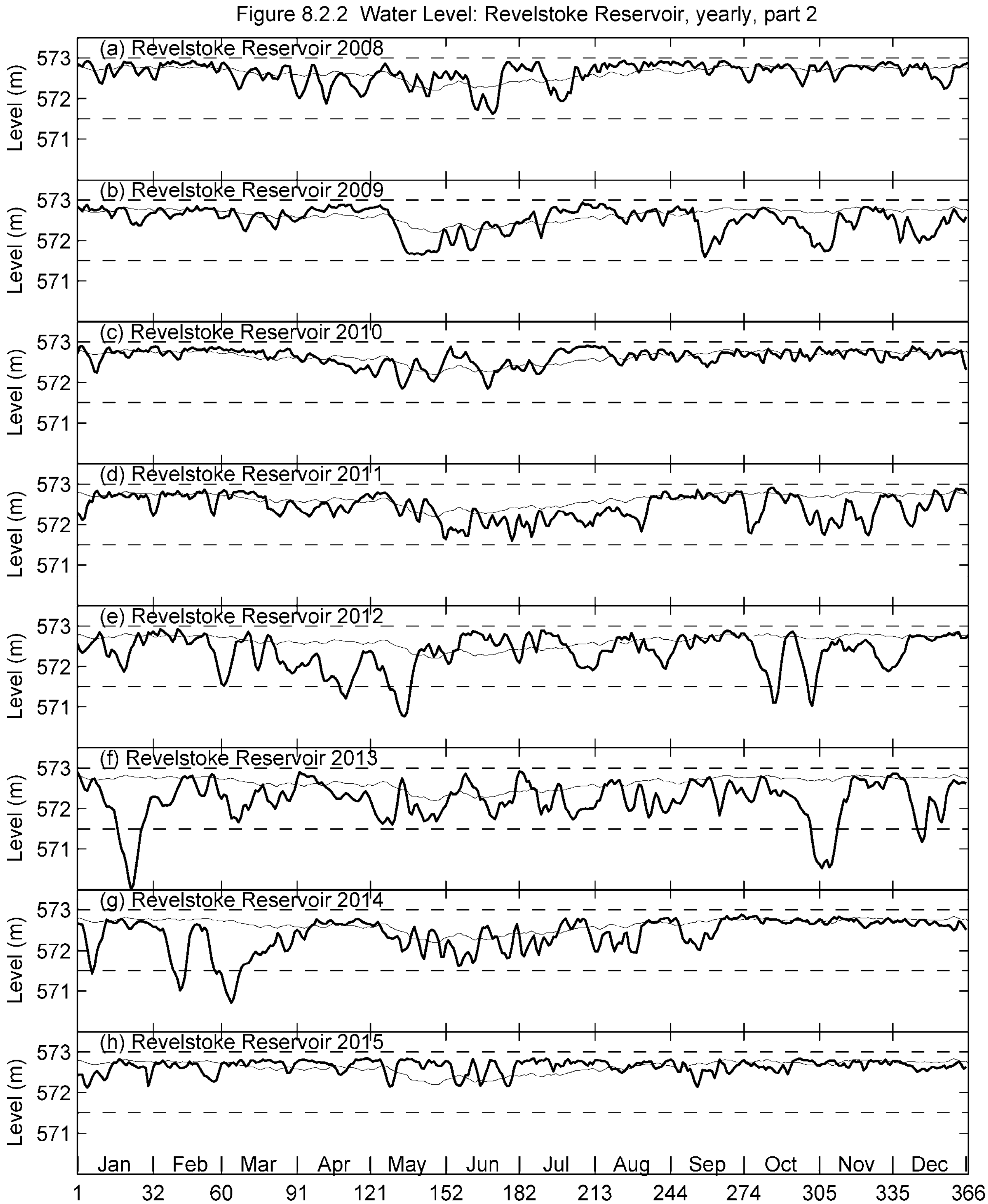


Figure 8.2.2. BC Hydro station "Revelstoke Lake Forebay", selected years (heavy line). Mean daily water level for 1988-2013 (light line) is shown for comparison. Dash lines mark the normal minimum and maximum elevation.

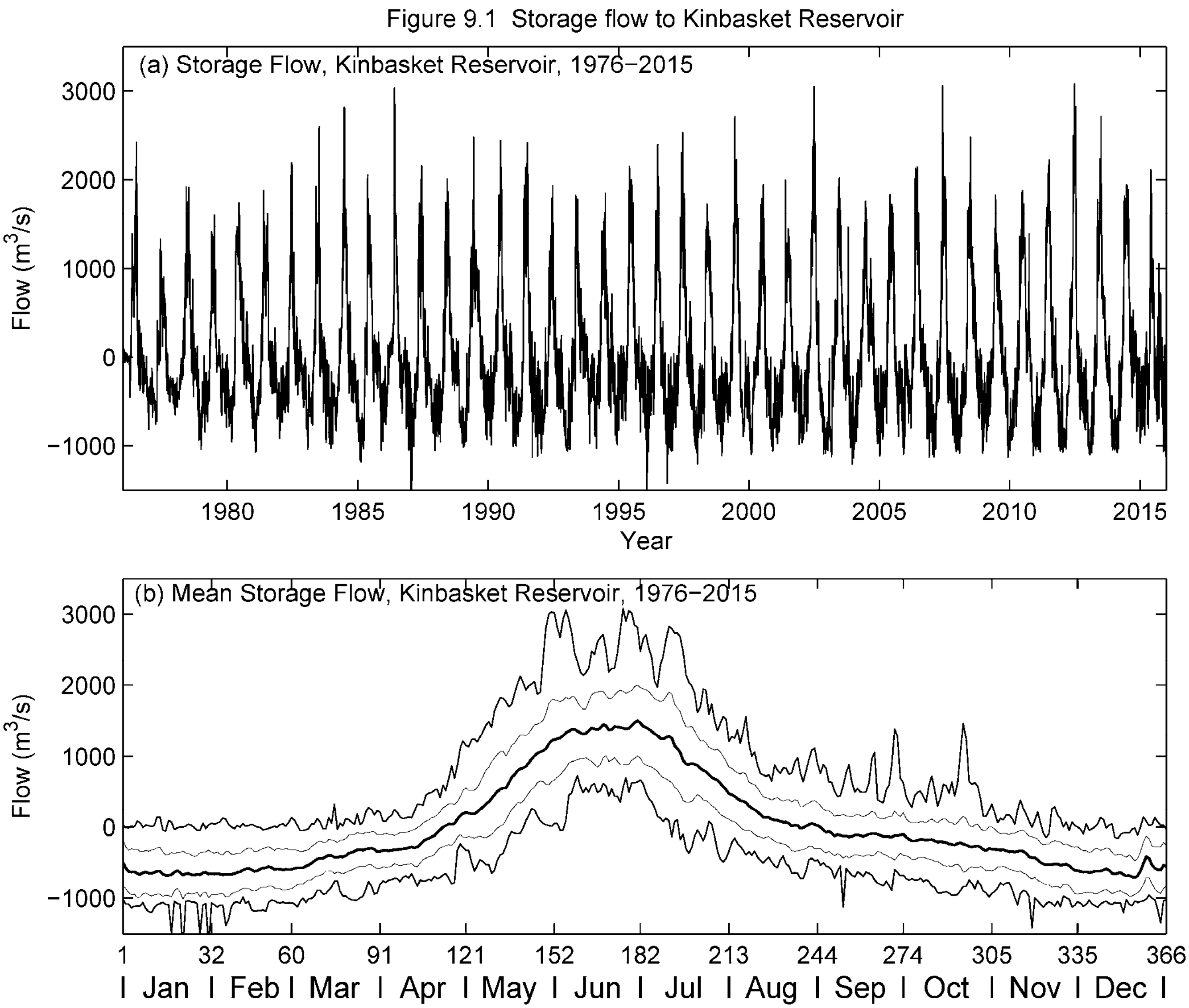


Figure 9.1. **(a)** Storage flow to Kinbasket Reservoir, 1976-2013. **(b)** Mean daily storage flow for 1976-2013. Mean (heavy line), maximum and minimum (medium lines) and mean ± one standard deviation (light lines).

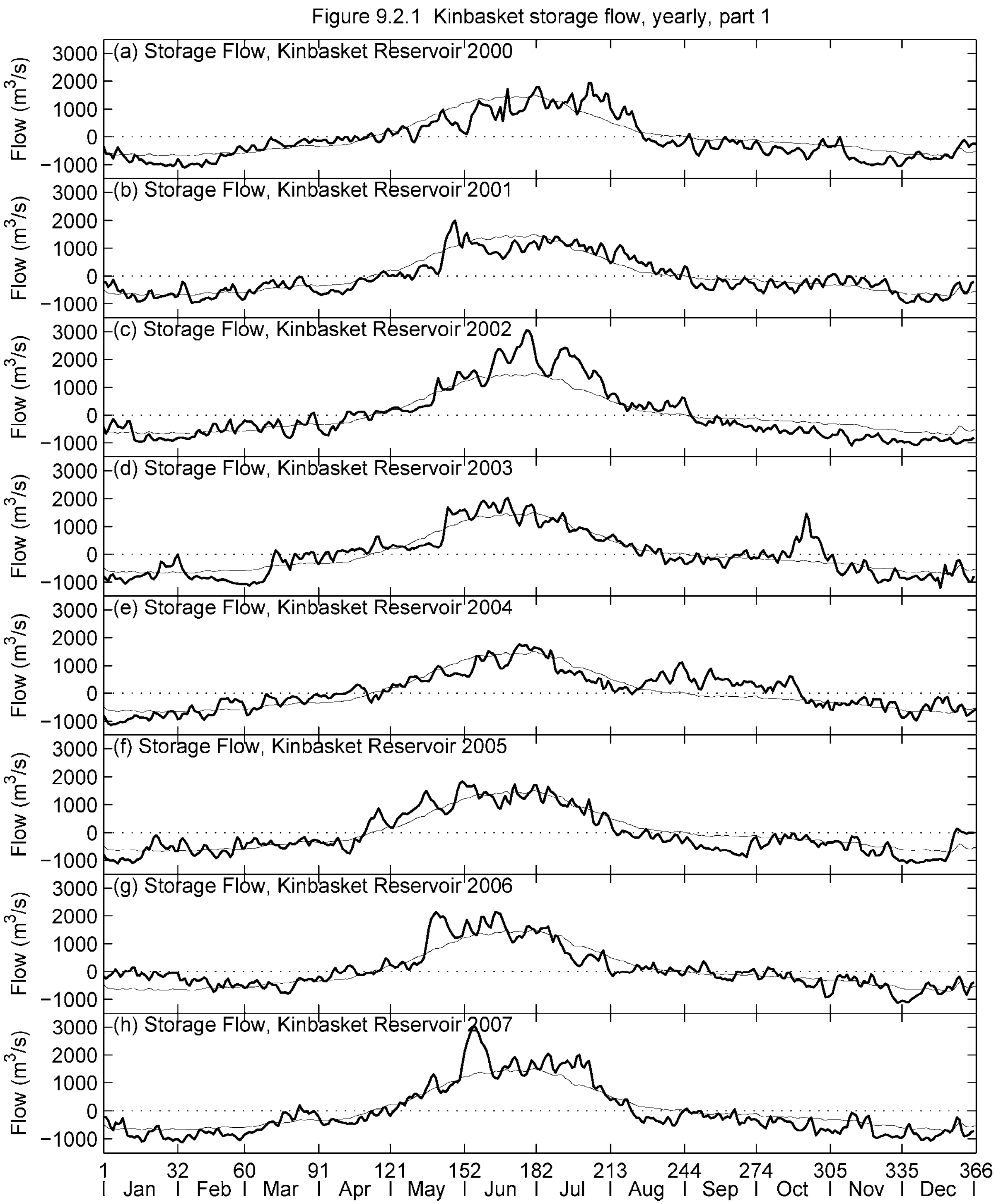


Figure 9.2.1. Storage flow to Kinbasket Reservoir, selected years (heavy line). Mean daily storage flow for 1976-2013 (light line) is shown for comparison.

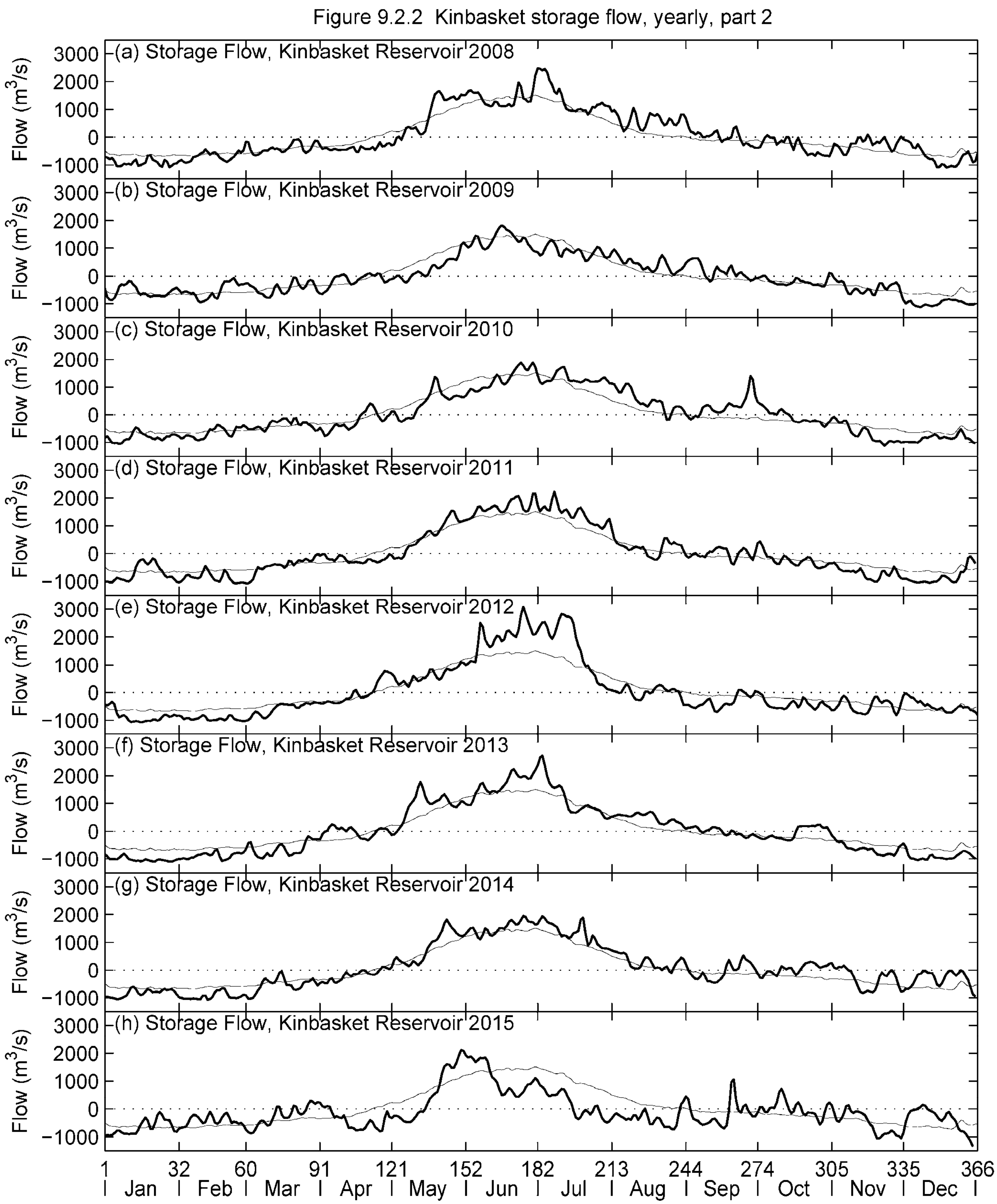


Figure 9.2.2. Storage flow to Kinbasket Reservoir, selected years (heavy line). Mean daily storage flow for 1976-2013 (light line) is shown for comparison.

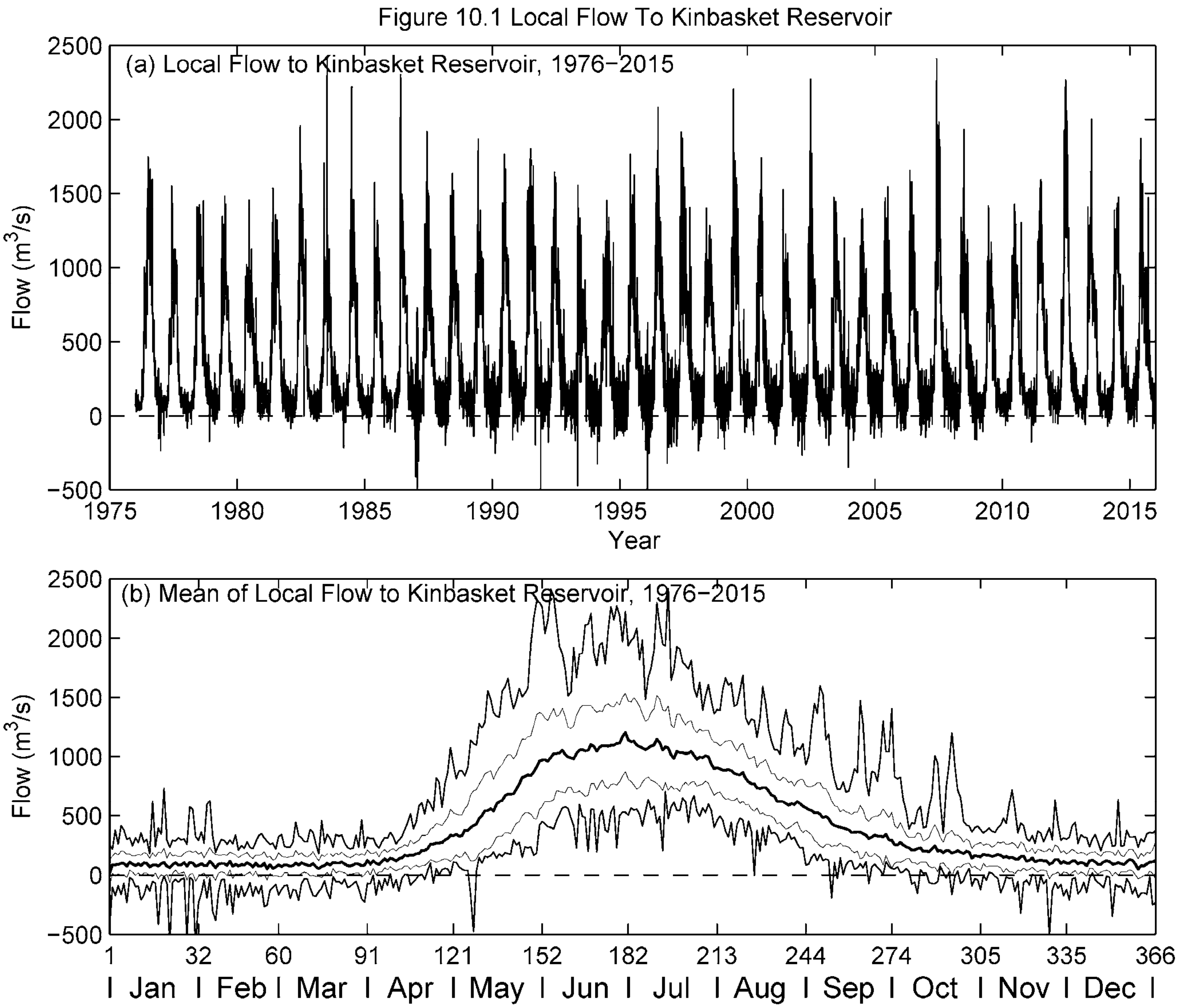


Figure 10.1. (a) Local flow to Kinbasket Reservoir, 1976-2013. **(b)** Mean daily local flow for 1976-2013. Mean (heavy line), maximum and minimum (medium lines) and mean ± one standard deviation (light lines).

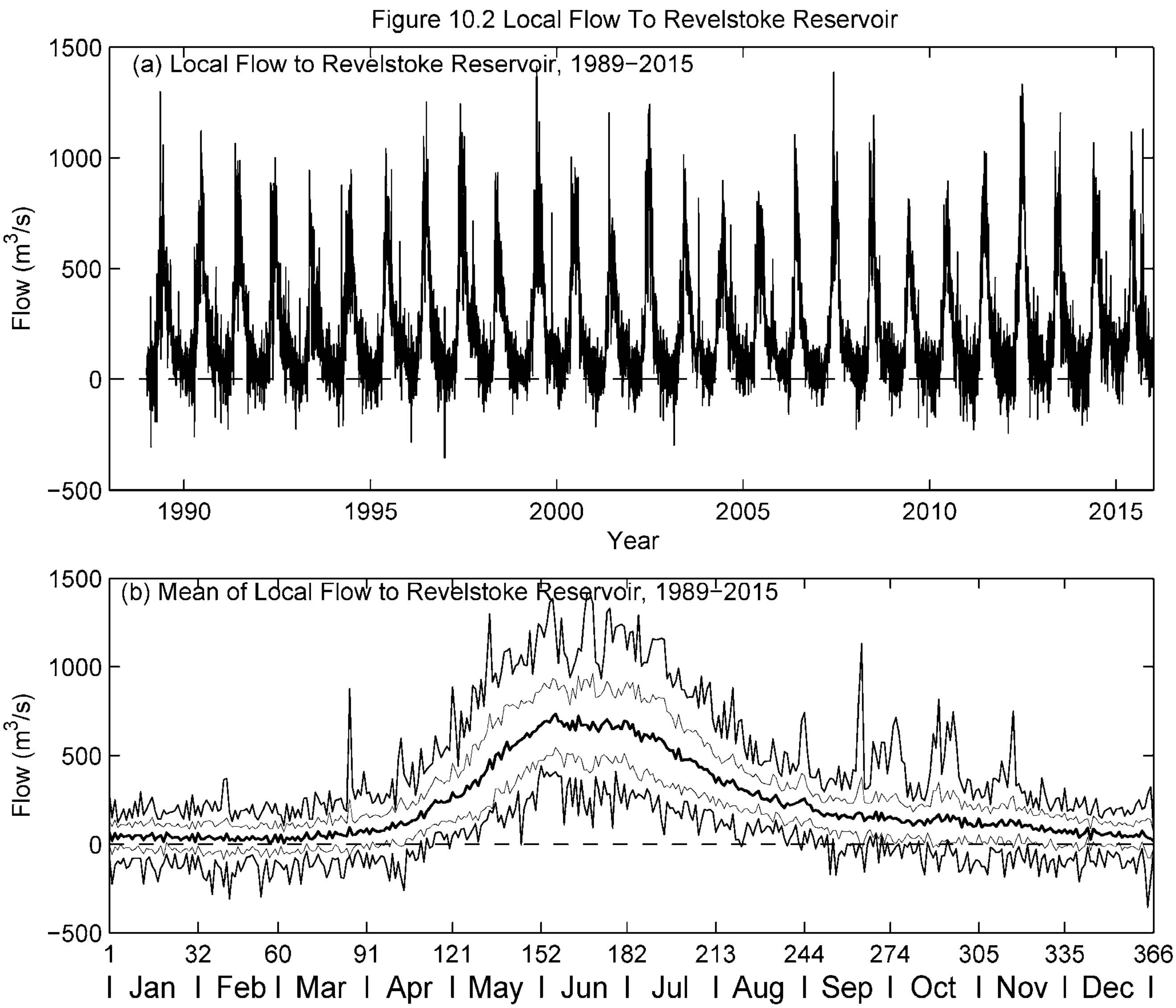


Figure 10.2. **(a)** Local flow to Revelstoke Reservoir, 1976-2013. **(b)** Mean daily local flow for 1976-2013. Mean (heavy line), maximum and minimum (medium lines) and mean ± one standard deviation (light lines).

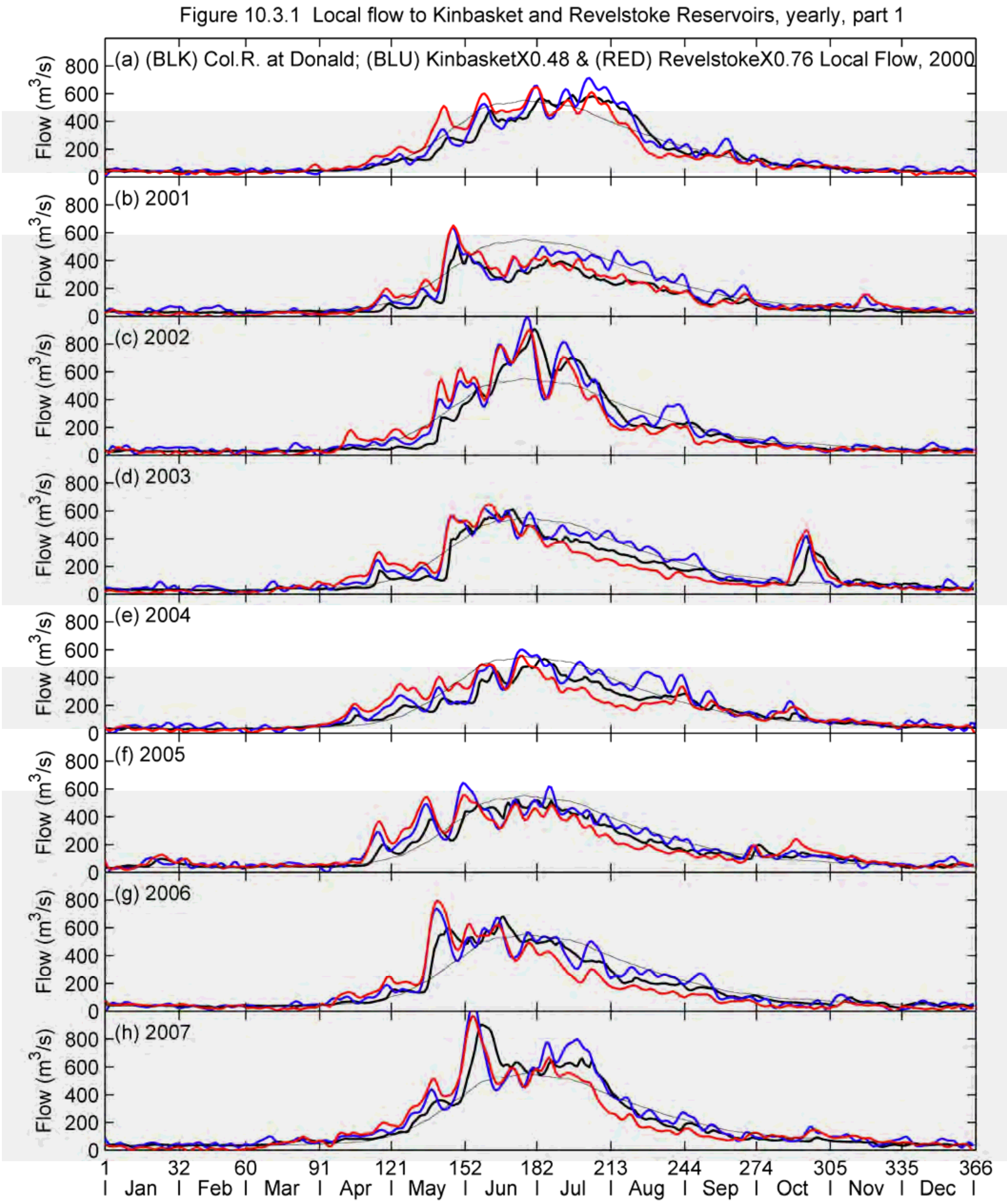


Figure 10.3.1. Local flow to Kinbasket and Revelstoke Reservoirs, selected years. The Columbia River at Donald, for the given year and the mean for 1944-2013 (light line) are shown for comparison. Local flows were scaled for comparison to the Columbia at Donald.

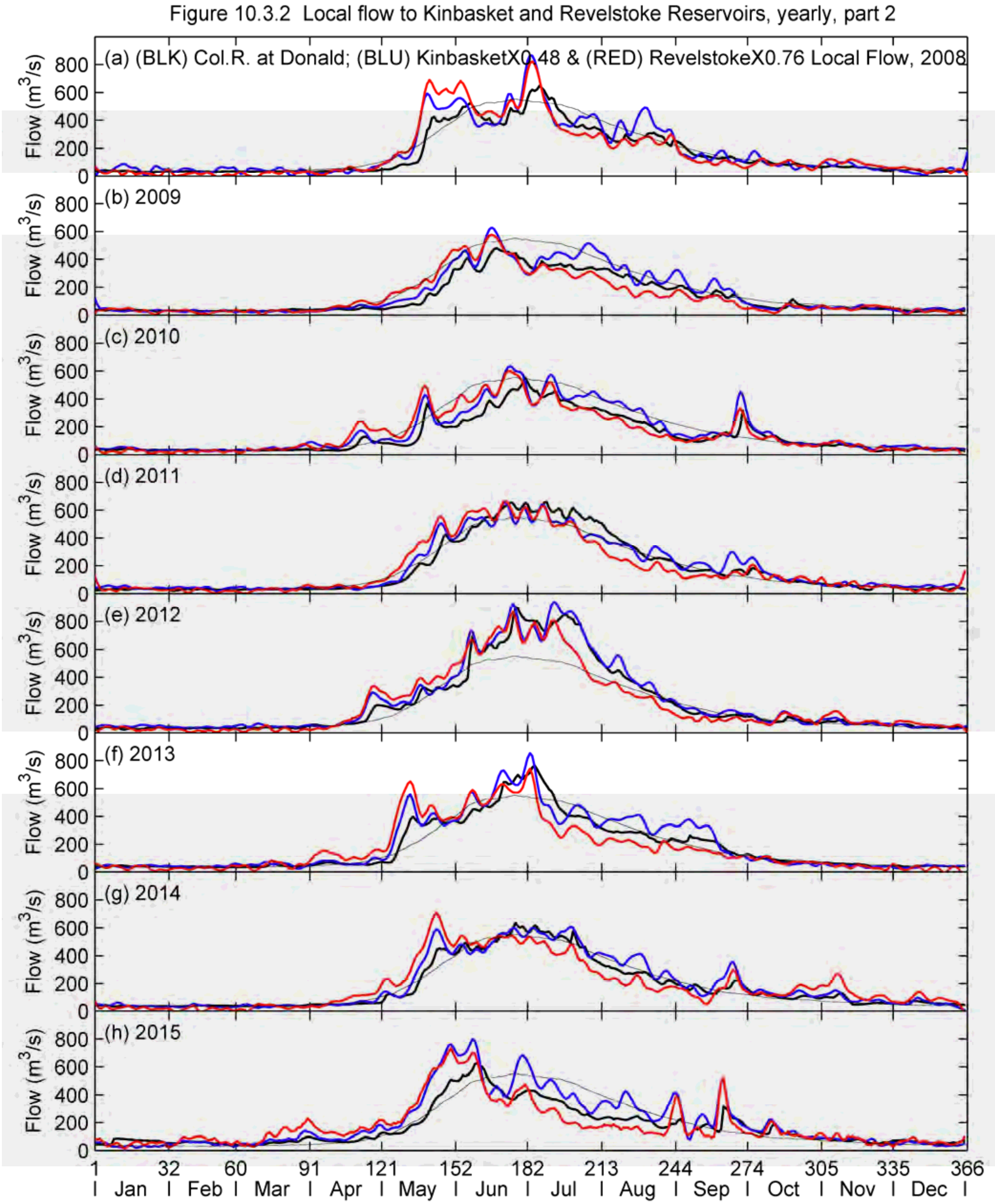


Figure 10.3.2. Local flow to Kinbasket and Revelstoke Reservoirs, selected years. The Columbia River at Donald, for the given year and the mean for 1944-2013 (light line) are shown for comparison.

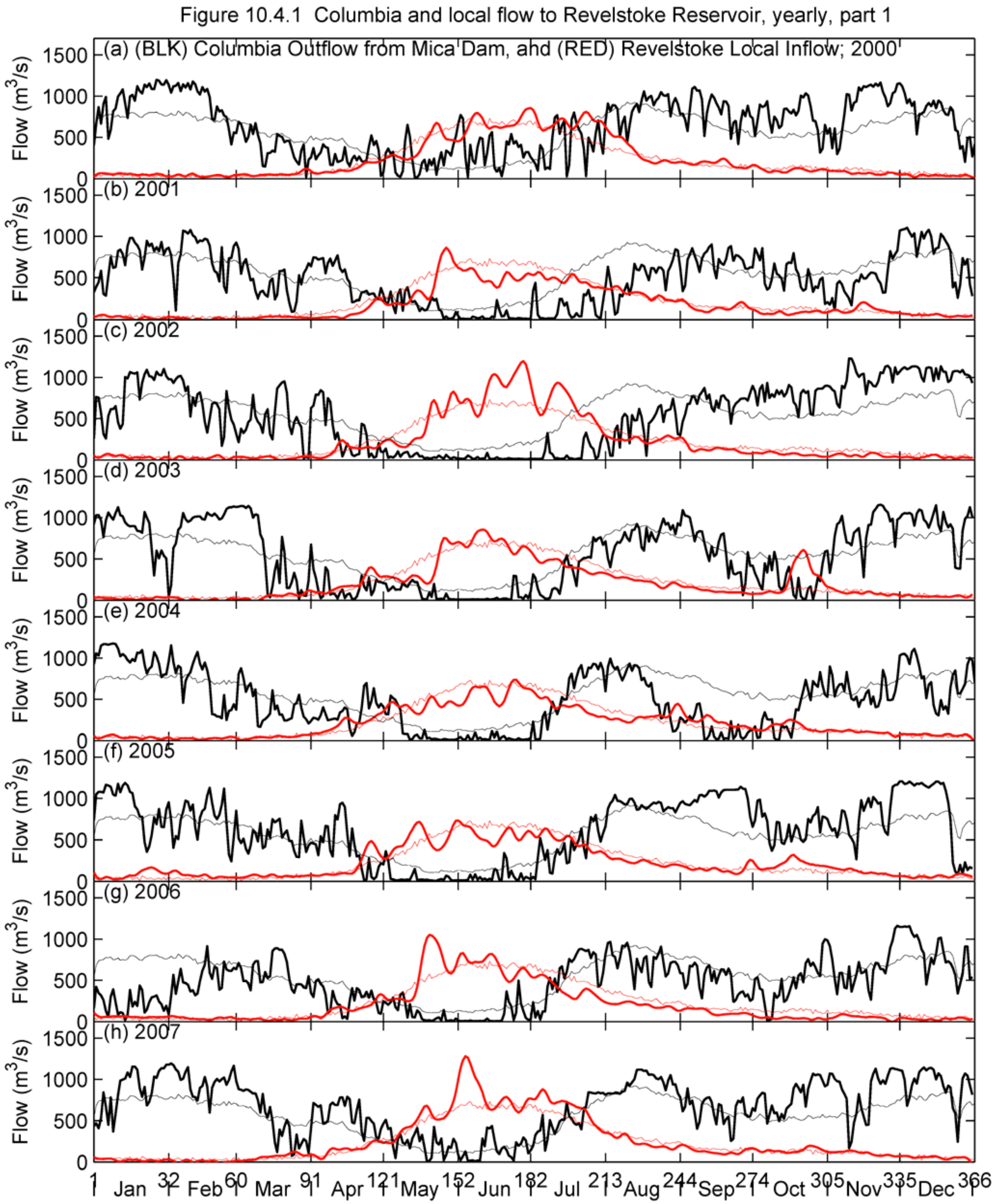


Figure 10.4.1. Comparison of the Columbia River at Mica dam to the local inflow to Revelstoke Reservoir, selected years. The mean flows (light lines) are shown for comparison.

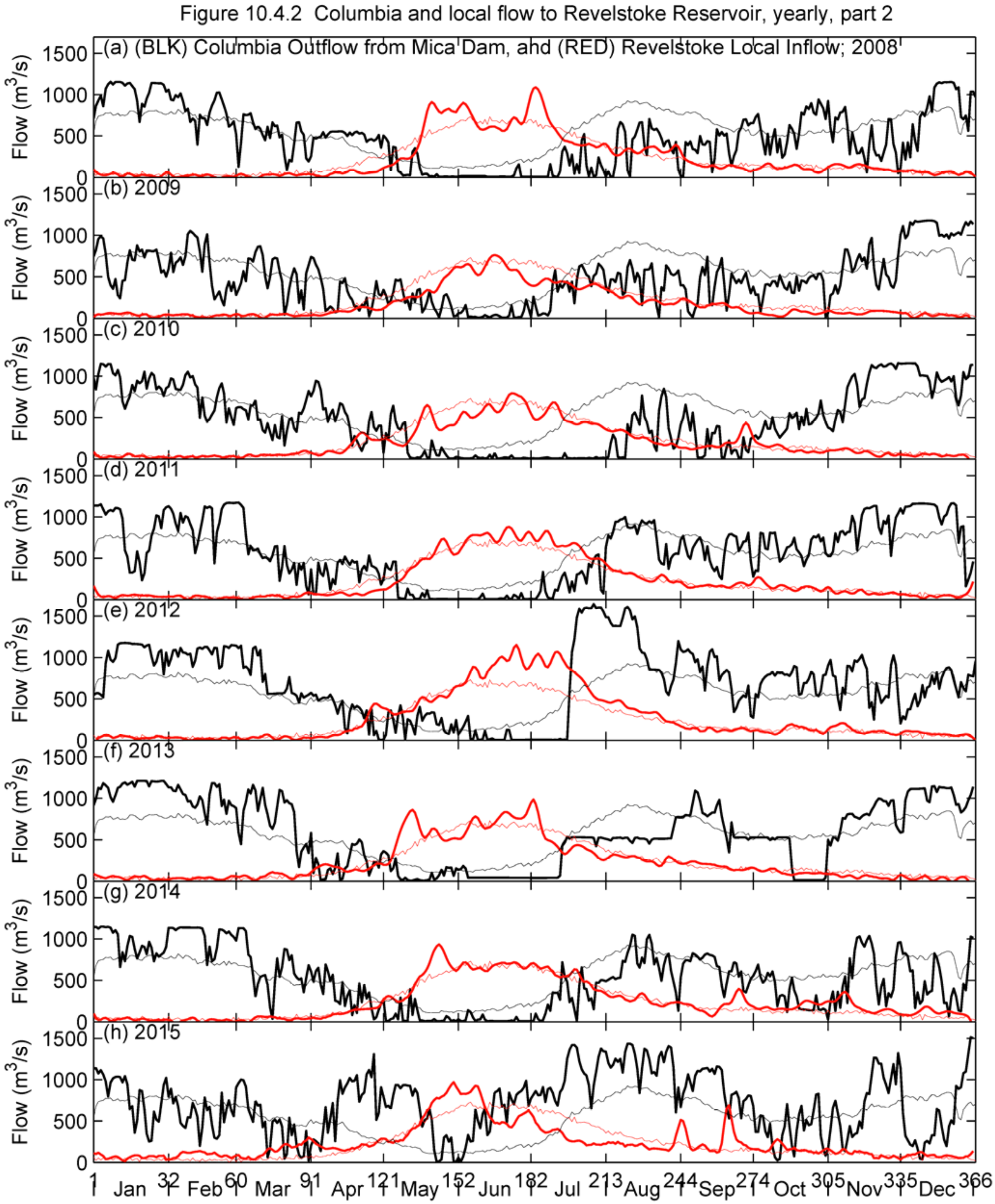


Figure 10.4.2. Comparison of the Columbia River at Mica dam to the local inflow to Revelstoke Reservoir, selected years. The mean flows (light lines) are shown for comparison. Local flows were scaled for comparison to the Columbia at Donald.

Appendix 1 Gauging Stations in the Kinbasket/ Revelstoke Drainage

Type*	Station #	Abbr	Station Name	Year	Drainage Area[1] (km^2)	Mean Flow[1] (m^3/s)	Yield (m/yr)
Columbia River							
Q	08NA045		Columbia River near Fairmont Hot Springs	1944-1996	891	10.4	0.37
WL	08NA004		Columbia River at Athalmer	1944-1984	1340	-	-
ND	08NA027		Columbia River near Athalmer	-	-	-	-
Q	08NA052		Columbia River near Edgwater	1950-1956	3550	58.7	0.52
Q	08NA002		Columbia River at Nicholson	1903-present	6660	107	0.51
Q	08NB005	coldo	Columbia River at Donald	1944-present	9710	172	0.56
ND	08NB008		Columbia River at Calamity Curve near Beavermouth	-	-	-	-
Q	08NB006	colsu	Columbia River at Surprise Rapids	1948-1966	14000	337	0.76
WL	08NB017	lking	Kinbasket Lake below Garrett Creek	1980-present	-	-	-
Q	08NB011	colbb	Columbia River at Big Bend Highway Crossing	1944-1949	16800	472	0.89
WL	08ND017	lkinm	Kinbasket Lake at Mica Dam	1974-present	-	-	-
Q	08ND007	colna	Columbia River above Nagle Creek	1947-1983	21500	567	0.83
ND	08ND010		Columbia River above Downie Creek	-	-	-	-
Q	08ND025	revpo	Revelstoke Project Outflow	1986-present	-	773	-
Q	08ND011	colsr	Columbia River above Steamboat Rapids	1955-1986	26400	796	0.95
Q	08ND002		Columbia River at Revelstoke	1912-1989	26700	854	1.01
WL	-	lreff	Revelstoke Reservoir	1984-present	-	-	-
Local Flow in Kinbasket Lake							
Q	08NB019	beavr	Beaver River near the Mouth	1985-present	1150	41.9	1.15
Q	08NB014	goldr	Gold River above Palmer Creek	1973-present	427	18.3	1.35
Q	08NC001	woodd	Wood River near Donald	1948-1972	956	40.1	1.32
Q	08NC003	canva	Canoe River at Valemont	1966-1967	368	*18.7*	1.60
Q	08NC002	cando	Canoe River near Donald	1947-1967	3290	105	1.01
Local Flow in Revelstoke Lake							
Q	08ND015	micac	Mica Creek near Revelstoke	1964-1965	82.4	*4.0*	1.53
Q	08ND012	golds	Goldstream River below Old Camp Creek	1954-present	938	39.0	1.31
Q	08ND019	kirby	Kirbyville Creek near the Mouth	1973-2005	112	6.14	1.73
Q	08ND009	downi	Downie Creek near Revelstoke	1953-1983	655	30.2	1.45
Other							
Q	08ND013	illgr	Illecillewaet River at Greeley	1963-present	1170	53.5	1.44

* Q - Flow, WL - Water Level, ND - No Data

[1] From Water Survey of Canada, values in italics were estimated

Appendix 2 Reference Elevations for the Mica and Revelstoke Projects

Kinbasket Reservoir Elevations

Elevation (ft)	**Elevation (m)**	**Storage (Mm^3)**	**Area (km^2)**	**Comments**
2500.0	762.0			Crest of dam
2486.5	757.9	26306.1	446.4	DSI, Dam Safety Incident level when spill gates are open
2484.9	757.4	26083.5	444.2	Expected maximum reservoir level during the PMF inflow event (11,780 m^3/s, 246,000 cfs)
2475.0	754.4	24770.7	431.0	Nmax, Normal maximum operating elevation. WLU, Water License Upper Limit
2319.4	707.0	9875.8	206.9	Nmin, Normal minimum pool level WLL, Calculated water license limit
2275.0	693.4			Sill elevation of 3.0 m W x 5.49 m H (10' W x 18' H) outlet gates (2)
2274.0	693.1			Top of intake conduit
2252.0	686.4			Sill elevation of power intakes (6) (Bottom of intake conduit)

Revelstoke Reservoir Elevations

Elevation (ft)	**Elevation (m)**	**Storage (Mm^3)**	**Area (km^2)**	**Comments**
1894.0	577.6			Crest of dam
1885.0	574.6	5449.4	118.2	DSI, Dam Safety Incident level when spill gates are open. Expected maximum reservoir level during the PMF inflow event (7100 m3/s, 250,000 cfs)
1880.0	573.0	5264.8	116.0	Nmax, Normal maximum operating elevation. WLU, Water License Upper Limit
1875.0	571.5	5089.9	113.6	Nmin, Normal minimum pool level
1830.0	557.8	3692.7	88.7	Minimum pool level (power intake limit)
1820.0	554.7			Minimum pool level (water license storage limit)
1772.6	540.3			Sill elevation of power intakes (6)

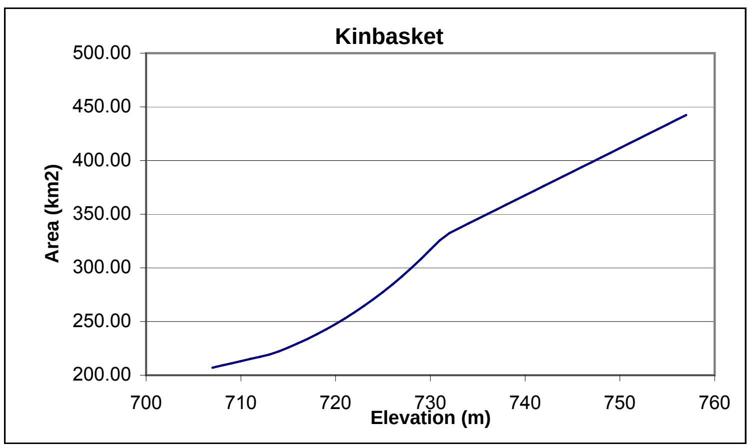
Appendix 3   Storage Elevation Curves

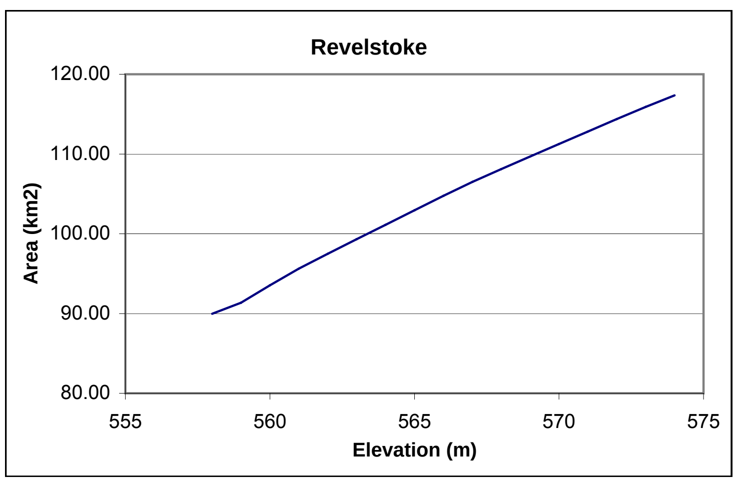
Kinbasket

Elevation (m)	Storage (Mm3)	Area (km2)
706	9.66997E+03	
707	9.87585E+03	206.94
708	1.00838E+04	209.03
709	1.02939E+04	211.09
710	1.05060E+04	213.12
711	1.07201E+04	215.13
712	1.09363E+04	217.11
713	1.11544E+04	219.27
714	1.13748E+04	222.16
715	1.15987E+04	225.73
716	1.18263E+04	229.56
717	1.20578E+04	233.67
718	1.22936E+04	238.05
719	1.25339E+04	242.71
720	1.27790E+04	247.69
721	1.30293E+04	252.97
722	1.32850E+04	258.59
723	1.35464E+04	264.54
724	1.38140E+04	270.85
725	1.40882E+04	277.54
726	1.43691E+04	284.60
727	1.46574E+04	292.06
728	1.49532E+04	299.94
729	1.52572E+04	308.24
730	1.55697E+04	316.98
731	1.58912E+04	325.72
732	1.62212E+04	332.33
733	1.65558E+04	336.89
734	1.68949E+04	341.27
735	1.72384E+04	345.65
736	1.75862E+04	350.04
737	1.79385E+04	354.42
738	1.82951E+04	358.81
739	1.86561E+04	363.20
740	1.90215E+04	367.59
741	1.93913E+04	371.98
742	1.97654E+04	376.38
743	2.01440E+04	380.77
744	2.05270E+04	385.17
745	2.09143E+04	389.57
746	2.13061E+04	393.96
747	2.17023E+04	398.36
748	2.21028E+04	402.77
749	2.25078E+04	407.17
750	2.29172E+04	411.57
751	2.33309E+04	415.98
752	2.37491E+04	420.38
753	2.41717E+04	424.79
754	2.45987E+04	429.20
755	2.50301E+04	433.61
756	2.54659E+04	438.02
757	2.59062E+04	442.43
758	2.63508E+04	

Revelstoke

Elevation (m)	Storage (Mm3)	Area (km2)
557.75	3.68827E+03	
558	3.71048E+03	89.97
559	3.80073E+03	91.35
560	3.89318E+03	93.55
561	3.98783E+03	95.62
562	4.08442E+03	97.50
563	4.18283E+03	99.31
564	4.28305E+03	101.13
565	4.38508E+03	102.94
566	4.48893E+03	104.75
567	4.59458E+03	106.49
568	4.70191E+03	108.11
569	4.81081E+03	109.68
570	4.92127E+03	111.25
571	5.03330E+03	112.81
572	5.14690E+03	114.38
573	5.26206E+03	115.91
574	5.37871E+03	117.36
575	5.49678E+03	





Appendix 2

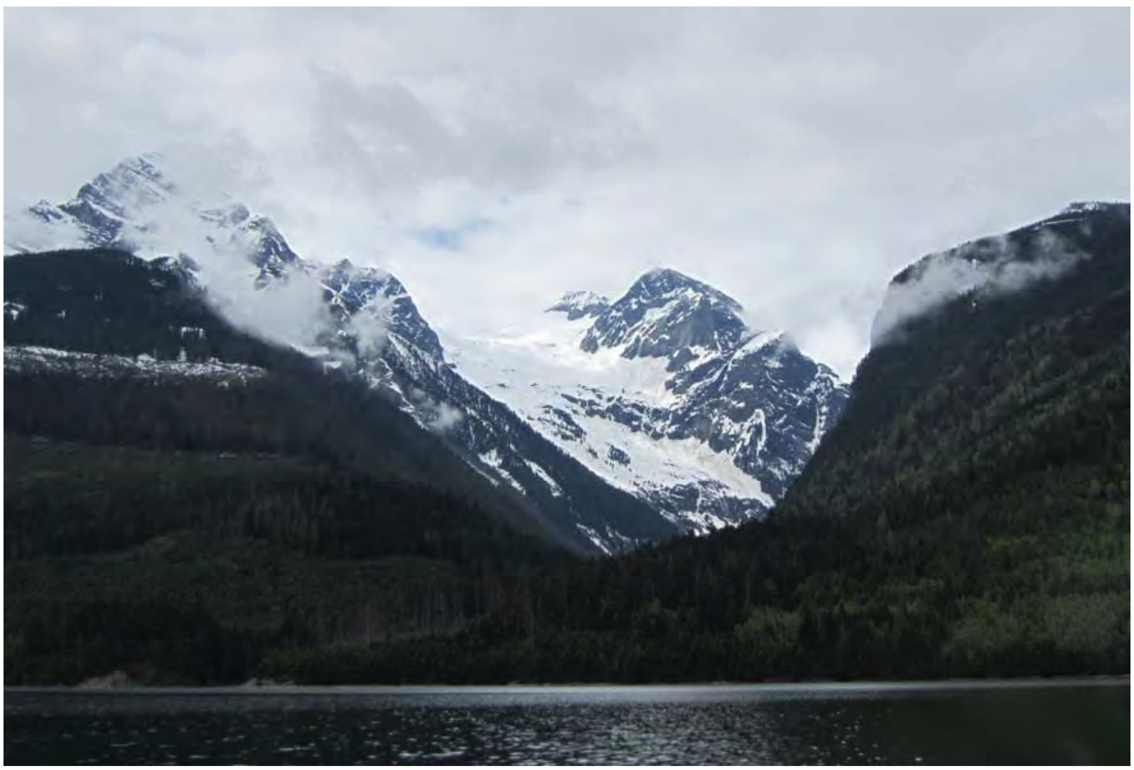
Tributary Water Quality Kinbasket and Revelstoke Reservoirs, 2015

Roger Pieters, Alyssia Law, and Greg Lawrence
University of British Columbia

Tributary Water Quality
Kinbasket and Revelstoke Reservoirs, 2014 and 2015

Roger Pieters[1,2], Alyssia Law[1] and Greg Lawrence[2]

[1] Earth and Ocean Sciences, University of British Columbia, Vancouver, B.C. V6T 1Z4
[2] Civil Engineering, University of British Columbia, Vancouver, B.C. V6T 1Z4



Revelstoke Reservoir, 20 May 2014

Prepared for

Karen Bray
British Columbia Hydro and Power Authority
1200 Powerhouse Road
Revelstoke B.C. V0E 2S0

January 18, 2017

Contents

List of Figures

1. Introduction

We report on the water quality data collected from tributaries to Kinbasket and Revelstoke Reservoirs in 2014 and 2015. These data were collected as part of the ongoing BC Hydro project entitled "CLBMON-3 Kinbasket and Revelstoke Ecological Productivity Monitoring".*

Two types of tributary samples have been collected:

1. Reference tributaries, sampled from April to November. Regular sampling of reference tributaries began in 2009 (Pieters *et al.,* 2011-2016); here we report on the data from the reference tributaries in 2014 and 2015.
2. Surveys of several tributaries at a given time. Sampling of tributary surveys were undertaken across both reservoirs in June and August 2008 (Pieters *et al.*, 2010), and on 7-8 July 2009 (Pieters *et al.*, 2011), and on 6 May 2013 (Pieters *et al.* 2016). A survey was not conducted in 2014 or 2015; see previous reports for details of tributary surveys.

2. Methods

Reference Tributary sample collection

There are five reference tributaries: Columbia River at Donald, Goldstream River, Beaver River, Kinbasket Reservoir (Mica Dam) Outflow, and Revelstoke Reservoir (Revelstoke Dam) Outflow. In the past, Columbia River at Donald, Goldstream River, Kinbasket Outflow, and Revelstoke Outflow were sampled by BC Hydro, and the Beaver River was sampled by Environment Canada. In 2013, BC Hydro began sampling the Beaver River as well.

Samples were collected from the point at which the tributary crossed a road. The Columbia River at Donald was sampled near the Highway 1 bridge. Mica outflow was sampled at the bridge downstream of the dam. Goldstream River, entering the east side of Revelstoke Reservoir, was sampled at Highway 23. Revelstoke outflow was sampled below the dam. Coordinates for the sample locations are given in Appendix 2.

The Beaver River was sampled at the east gate of Glacier National Park by Environment Canada, and this location represents about half of the total drainage of the Beaver River. Additional sampling of the Beaver River by BC Hydro began in 2013, at sampling sites near the confluence with the Kinbasket Reservoir. Beaver River was sampled near Kinbasket Resort when water levels were low, but was sampled upstream as water levels increased; see Appendix 2 for detail.

* In 2003, eight tributaries to Revelstoke Reservoir were sampled as part of an embayment study (K. Bray, personal communication).

Sample Processing

Water samples were collected in a bucket and then transferred into sample bottles. Temperature was measured with a handheld thermometer. Filtration was done later the same day; water samples were either frozen or kept on ice and shipped within 48 hours to Maxxam Analytics (4606 Canada Way, Burnaby, British Columbia). Note that in previous years (2008-2012) samples were analyzed by the Cultus Lake Salmon Research Laboratory, Department of Fisheries and Oceans (4222 Columbia Valley Highway, Cultus Lake, British Columbia). In all years, samples were analyzed for the water quality parameters listed in Table 1. Laboratory methods are summarized in Appendix 1. The tributaries sampled are listed in Appendix 2. Data are given in Appendix 3. A problem was found with alkalinity data prior to 2013; this report shows corrected alkalinity for all years (see Appendix 1 for detail).

Table 1 Parameters measured

Parameter	Units	Symbol	Detection Limit (Maxxam)
pH		pH	
Conductivity (C25)	µS/cm	Cond	1 µS/cm
Nitrate and Nitrite (NN)	µg/L N	NN	2 ug/L
Soluble Reactive Phosphorus (SRP)	µg/L P	SRP	1 ug/L
Total Dissolved Phosphorus (TDP)	µg/L P	TDP	2 ug/L
Total Phosphorus (TP)*	µg/L P	TP	2 or 20 ug/L
Turbidity (Turb)	NTU	Turb	0.1 NTU
Alkalinity (Alk)	$mgCaCO_3/L$	Alk	0.5 $mgCaCO_3/L$
Water Temperature (T)	^oC	T	

*A color/turbidity correction for TP is only available for 2008-2012 data.

3. Reference Tributaries

Intensive sampling of the reference tributaries began in 2009. Comparison of the 2009 through 2015 data is shown for April to November in Figures 3.1 to 3.6. The exception is Figure 3.3 for the Beaver River which is plotted from January to December as data were available throughout the year.

Columbia River at Donald (Figure 3.1)

Consider first the Columbia River at Donald which flows into Kinbasket Reservoir. Data for 2009 to 2015 are shown in Figures 3.1. River flow is shown in Figure 3.1a; flow is dominated by spring freshet which peaks from early June to mid-July.

River temperature is shown in Figure 3.1b. The Columbia at Donald, having wound its way through the Rocky Mountain Trench, was relatively warm peaking at 15 - 18 ºC in July and August each year. The conductivity (C25), shown in Figure 3.1c, declined through the freshet to about half by mid-summer. The turbidity, shown in Figure 3.1d, was highly variable while pH remained slightly alkaline throughout the sampling period (Figures 3.1e).

In a well oxygenated environment such as a river, nitrite will be low, and data for nitrate and nitrite (NN) give the predominant nitrate concentration. Nitrate concentrations in the Columbia River at Donald (Figure 3.1f) declined rapidly during freshet. For example, nitrate declined by about 7 times from 206.0 µg/L on 27 May 2014 to 29.9 µg/L on 9 July 2014, and declined by about 5 times from 185.0 µg/L on 7 May 2015 to 38.3 µg/L on 28 July 2015.

Note the peak in nitrate occurs at the beginning of freshet; much of this nitrate is thought to come from the snow that received atmospheric deposition of nitrogen over the winter. The subsequent decrease in nitrate reflects depletion of the supply of nitrate from the snowpack and from shallow soil water pools before the end of freshet (Sebestyen *et al*., 2008).

Soluble reactive phosphorus (SRP), also known as orthophosphate (OP or PO_4), was low and variable over the years (Figure 3.1g). The SRP values range from < 1 to 6.2 µg/L and < 1 to 7.0 µg/L in 2014 and 2015, respectively. The detection limit for SRP was 1 µg/L.

Total dissolved phosphorus (TDP) values showed little variability in 2014 and 2015 (Figure 3.1h). The TDP values ranged from < 2 to 3.6 µg/L in 2014, and from < 2 to 5.0 µg/L in 2015. The detection limit for TDP was 2 µg/L.

Total phosphorus (TP) ranged from 2.3 to 107.1 µg/L in 2008 to 2015; the values ranged from 2.6 to 60.5 µg/L in 2014, and from 2.3 to 17.1 µg/L in 2015 (Figure 3.1i). Particulate phosphorus can be estimated as the difference between total phosphorus and total dissolved phosphorus, PP = TP - TDP. In glacially dominated systems, with high turbidity, much of the total phosphorus measured may have been extracted from particulate minerals (e.g. apatite) by the step in the analysis in which the sample undergoes digestion with persulphate (Appendix 1). As a result, for tributaries with high PP, it is likely that much of this phosphorus is of low biological availability.

In 2014 and 2015, the values for the NN:TDP ratio (by weight) in the Columbia at Donald were all > 10 suggesting tributary nutrients were phosphorus limited. However, in previous years this was not generally the case for the Columbia at Donald, with the NN:TDP ratio falling below 10 during the summer. In particular, in the summer of 2012, NN:TDP ratios with values less than 10 persisted until late October (Figure 3.1j). Low tributary nitrate during summer may result in nitrogen and phosphorus co-limitation in the reservoir.

Goldstream River (Figure 3.2)

Data from 2009 to 2015 for the Goldstream River are shown in Figure 3.2. Flow in the Goldstream River (Figure 3.2a) shows a similar pattern to the Columbia at Donald with spring freshet from early June to mid-July, followed by gradually declining flow into August. Notable is a peak in late September 2015, due to an autumn rainstorm.

Compared to the Columbia River at Donald, the Goldstream River was cooler, with July temperatures of only 7 - 12 ºC with the exception of 14 °C measured on 28 July 2009 (Figure 3.2b).

The conductivity (C25) in Goldstream River (Figure 3.2c) declined to approximately half of its spring value by mid-summer. Unlike in 2015, when data were available from mid-April, in most years data began later after C25 had already begun to decline. From September to December, C25 gradually increased, and, in December 2015, reached pre-freshet levels.

Turbidity was generally below 20 NTU, except for one outlier of 198 NTU on 28 July 2009 (Figure 3.2d). The pH remained slightly alkaline varying from about 8 pH units in winter to a range of 7.2 to 7.8 pH units during summer (Figure 3.2e).

Similar to the Columbia River at Donald, the Goldstream River experienced a peak in nitrate (NN) concentration during freshet (Figure 3.2f). From a high of 411 µg/L on 26 May 2014, the nitrate concentration in Goldstream River declined by a factor of 5 to 76.9 µg/L on 8 July 2014 (Figure 3.2f). Similarly, in 2015, the nitrate concentration declined by a factor of 6.5, from 413 µg/L on 6 May 2015 to 63.8 µg/L on 27 July 2015.

In 2014 and 2015, soluble reactive phosphorus (SRP) was similar to previous years with the exception of a few slightly higher values in the fall (Figure 3.2g). Total dissolved phosphorus (TDP) concentrations for 2014 and 2015 were relatively constant around the detection level of 2.0 µg/L in 2014 and 2015 (Figure 3.2h). The maximum concentration of TDP was 3.8 µg/L in 2014 and 6.3 µg/L in 2015.

Total phosphorus (TP) concentrations for 2014 ranged from 2.2 µg/L to 36 µg/L. In 2015 values of TP were generally observed to be below 10 µg/L with the exception one sample with 45.1 µg/L collected on 7 April 2015. Similar to Columbia at Donald, NN:TDP values in 2014 to 2015 were all greater than 10, with four values exceeding 100 (Figure 3.2j). These high values suggest phosphorus limitation occurring at Goldstream.

Beaver River (Figure 3.3)

Similar to Goldstream River and the Columbia River at Donald, flow in Beaver River was dominated by spring freshet (Figure 3.3a). However, compared to Goldstream and the Columbia at Donald, the temperature in Beaver River was cooler, with a maximum of 8 °C in 2014 and 2015 (Figure 3.3b).

The conductivity (C25) in 2014 declined from 216 µS/cm on 24 March 2014 to 70 µS/cm on 30 September 2014 (Figure 3.3c). An outlier of 619 µS/cm was recorded on 17 November 2014 and removed from Figure 3.3c. Conductivity values in 2015 were similar, with a minimum value of 62 µS/cm in August.

Turbidity in Beaver River for 2014 remained relatively constant (Figure 3.3d) ranging between 1.3 NTU (22 April 2014) and 10.7 NTU (27 May 2014). In comparison, 2015 experienced much more variability, with values ranging from 0.8 (7 May 2015) to a peak of 62 NTU (9 June 2015).

The pH in Beaver River for 2014 and 2015 remained slightly alkaline (Figure 3.3e). Note that samples further down the river (near confluence) were slightly more acidic in summer compared to samples collected near East Park Gate by Environment Canada. The average pH for both years was approximately 7.8 pH units.

Data from 2014 and 2015 followed the pattern of previous years (Figure 3.3f). Values of NN were low in winter and increased rapidly at the start of freshet. Both years showed peaks greater than 300 µg/L. This spring peak in NN then dropped dramatically after the start of freshet, to a low of approximately 70 µg/L in summer, and then gradually increased again to winter levels of above 100 µg/L by December.

In previous years, the concentrations of soluble reactive phosphorus (SRP) were low (Figure 3.3g), near the detection level (1 ug/L). The concentration of SRP remained low in 2014 and 2015, although a few slightly higher values were observed in 2014 (up to 5.2 ug/L), which may be related to the change in lab (Appendix 1).

Total phosphorus (TP) was variable in Beaver River (Figure 3.3i) ranging between the detection limit (<2.00 ug/L) and 17.4 ug/L. The NN:TDP ratio also remained high in Beaver River, with all values greater than ten.

Kinbasket and Revelstoke Outflows (Figures 3.4 and 3.5)

Note that Revelstoke Reservoir backs all the way to the foot of Mica Dam (Kinbasket Reservoir); as a result, samples of Kinbasket outflow taken from the riverine section below the dam can be influenced by Revelstoke Reservoir when outflow from Kinbasket is low, which typically occurs from late spring to early summer (Figures 3.4a). Note also that Appendix 3.1 refers to the location at which Kinbasket outflow was sampled as "Columbia at Mica Outflow", and the location at which Revelstoke outflow was sampled as "Columbia above Jordan".

As in previous years, the temperature of the outflows from the dams were cold (≤12 ºC) as a result of the deep intakes (Figures 3.4b and 3.5b). There were a few exceptions for the Kinbasket (Mica Dam) outflow; for example, in July and August 2010 when the temperature was warmer (Figure 3.4b). At low flow, the temperature below Mica Dam may have been influenced by Revelstoke Reservoir.

The conductivity of the outflow from the Kinbasket and Revelstoke Reservoirs was relatively steady in 2014 and 2015, with the occasional lower value during low outflow from Mica Dam as in previous years (Figures 3.4c and 3.5c). The turbidity of the outflow from both Mica and Revelstoke was very low, generally < 2 NTU (Figures 3.4d and 3.5d); the average turbidity for the Kinbasket outflow was 1.2 and 0.53 NTU in 2014 and 2015 respectively, and for Revelstoke outflow was 0.55 and 0.61 NTU in 2014 and 2015 respectively, which is similar to previous years. Like the tributaries, the pH was relatively constant and slightly alkaline (Figures 3.1e and 3.5e). There were some lower values of pH below Mica Dam from mid-May to mid-July, again corresponding to low outflow conditions.

Nitrate and nitrite concentrations (NN) in the Kinbasket outflow were generally constant throughout the year at approximately 100 µg/L (Figure 3.4f). The exceptions occurred mainly during spring when outflow was low. Exceptions include 319.0 µg/L in May 2014; 212.0 µg/L on 7 October 2014; and 205 µg/L in May 2015. In the outflow from Revelstoke, NN was also relatively constant throughout the year, varying from 70 to 170 µg/L (Figures 3.5f). The exceptions are two values in November and December 2015, reaching 289.0 µg/L on 8 December 2015; the cause of these two exceptions is not known.

For both Kinbasket and Revelstoke outflows, SRP concentrations were close to the detection limit and generally below 4 µg/L (Figures 3.4g and 3.5g), with the exception of one value of 7.2 µg/L in the Kinbasket outflow on 5 October 2016. Both TDP (Figures 3.4h-3.5h) and TP (Figures 3.4i-3.5i) were low and relatively constant in the outflow of both dams (approximately 5 µg/L). The NN:TDP ratio for the Kinbasket and Revelstoke outflows exceeded 10 throughout 2014 and 2015, suggesting nutrients from these sources were phosphorus limited (Figures 3.4j and 3.5j). One exception to this was a NN:TDP ratio recorded on 8 April 2015, where the NN:TDP ratio was only 4 due to an unusually high value of TDP (29.3 µg/L).

4. Discussion

Most of the tributaries to Kinbasket and Revelstoke Reservoirs are remote and difficult to access, making it prohibitive to collect enough samples from each site to show the seasonal variation. As a result intensive sampling of a set of reference tributaries has been undertaken to provide an indicator of seasonal variability.

Another example of seasonal variability is given by the long record of water quality data available for the Illecillewaet River, which is located just south of the Revelstoke Reservoir (Figures 3.6 and 3.7). The Illecillewaet is the largest local inflow to the Arrow Reservoir, drains 1170 km^2, and includes flow of glacial origin. Water quality data for 1997 to 2001 are shown in Figure 3.6. Also shown in grey is the flow from WSC Station 08ND013, Illecillewaet at Greeley. Similar to that observed in the reference tributaries, there is a clear seasonal cycle in C25 and nitrate, with concentrations high during the start of freshet and then decreasing rapidly to lower values during the summer (Figures 3.6a and 3.6d). In late August, the values begin to increase again. Also shown for reference are water temperature, pH, NH_3, SRP, TDP, and TP (Figures 3.6).

Figure 3.7 compares the seasonal evolution of the flow, C25 and NN in the Illecillewaet River during these five years, 1997-2001. The onset of freshet occurred between early and mid-May. For example, in 1998 a large peak in freshet flow began at the start of May while freshet was delayed toward the end of May in 2001. There is a corresponding variation in the timing of the decline in C25 (Figure 3.7b). The decline in NN occurs more gradually through May and June to very low values in July and August (Figure 3.7c). Overall, NN declined from 420-480 μg/L in May to 50-100 μg/L in mid-summer. A similar decline in NN is seen in other tributaries to the Arrow Reservoir (e.g. Pieters *et al.,* 2003).

5. Conclusions

Based on these data, and those of previous years, the tributaries to both Kinbasket and Revelstoke Reservoirs are low in nutrients. Soluble reactive phosphorus (SRP) was very low in both basins, generally close to the detection limit. Total dissolved phosphorus (TDP) was also low, about 5 μg/L. Total phosphorus (TP) was highly variable, reflecting the glacial origin of many of the tributaries, and much of the TP is likely of inorganic origin with low biological availability. In the presence of glacial inflow, TDP is preferred over TP as a measure of available phosphorus.

In the presence of oxygen, concentrations of nitrate and nitrite (NN) are typically dominated by nitrate. Nitrate in the outflow from Kinbasket and Revelstoke Reservoirs was approximately 100 μg/L. For comparison, nitrate in the outflow from Arrow Reservoir was 200 μg/L (Pieters *et al.,* 2003).

For an N:P ratio greater than 10 (by weight), phosphorus is expected to limit phytoplankton productivity (Horne and Goldman, 1994). The N:P ratio, based on NN and TDP, is greater than 10 for the reference tributaries which suggests phosphorus limitation, with the notable exception of Columbia River at Donald in some summers, when the N:P ratio declined below 10, suggesting phosphorus and nitrogen co-limitation. The N:P ratio was well above 10 for the outflow from both reservoirs.

Acknowledgements

Samples were collected by B. Manson, P. Bourget and K. Bray. Funding was gratefully provided by BC Hydro. We thank J. Bowman, A. Sharp, K. Lywe, A. Quainoo and T. Rodgers for assistance, and for support from the UBC Work-Learn program. G. Lawrence is grateful for the support of the Canada Research Chair program.

References

APHA 1975. Standard Methods for the examination of Water and Wastewater. 14th edn. American Public Health Association APHA-AWWA-WPCF. John D. Lucas Co. Baltimore.

Horne A. and C. Goldman, 1994. Limnology 2nd Edition. McGraw Hill Inc., New York.

Pieters, R., L. Vidmanic, S. Harris, J. Stockner, H. Andrusak, M. Young, K. Ashley, B. Lindsay, G. Lawrence, K. Hall, A. Eskooch, D. Sebastian, G. Scholten and P.E. Woodruff. 2003. Arrow Reservoir fertilization experiment, year 3 (2001/2002) report. RD 103, Fisheries Branch, Ministry of Water, Land and Air Protection, Province of British Columbia.

Pieters, R., A. Akkerman, and G. Lawrence. 2010. Tributary Water Quality, Kinbasket and Revelstoke Reservoirs, 2008. University of British Columbia. 28 pp. Appendix 2 in BC Hydro. 2010. Kinbasket and Revelstoke Reservoirs Ecological Productivity Monitoring. Progress Report Year 1 (2008). BC Hydro, Water Licence Requirements. Study No. CLBMON-3. 4pp. + appendices.

Pieters, R., H. Keller and G. Lawrence. 2011. Tributary Water Quality, Kinbasket and Revelstoke Reservoirs, 2009. 52 pp. Appendix 2 in BC Hydro 2011. Kinbasket and Revelstoke Reservoirs Ecological Productivity Monitoring. Progress Report Year 2 (2009). BC Hydro, Water Licence Requirements. Study No. CLBMON-3. 4pp. + appendices.

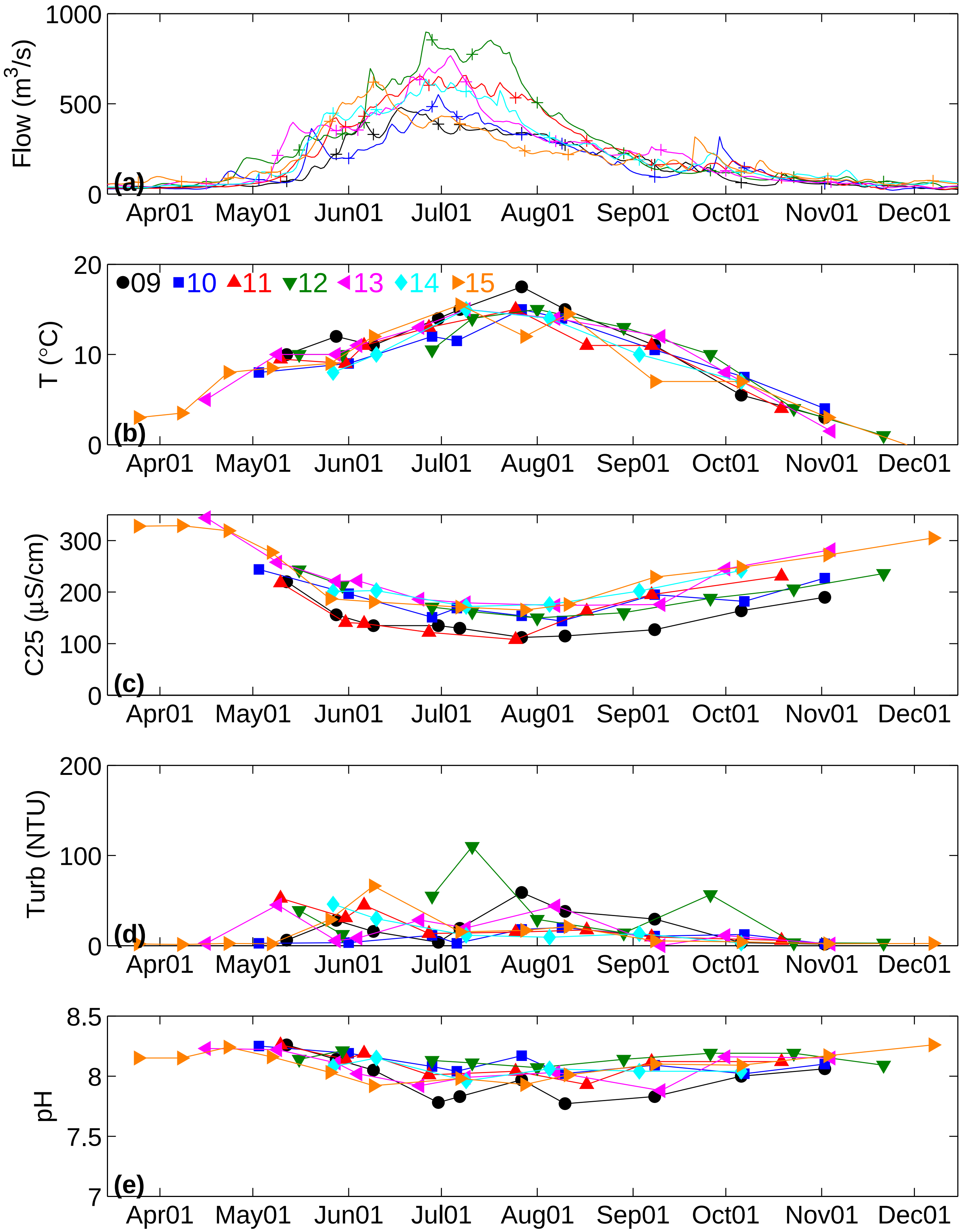
Pieters, R. and G. Lawrence. 2012. Tributary Water Quality, Kinbasket and Revelstoke Reservoirs, 2010. 30 pp. Appendix 2 in Bray, K.E. 2012. Kinbasket and Revelstoke Reservoirs Ecological Productivity Monitoring. Progress Report Year 3 (2010). BC Hydro, Environment. Study No. CLBMON-3. 4pp. + appendices.

Pieters, R. and G. Lawrence. 2013. Tributary Water Quality, Kinbasket and Revelstoke Reservoirs, 2011. 34 pp. Appendix 2 in Bray, K.E. 2012. Kinbasket and Revelstoke Reservoirs Ecological Productivity Monitoring. Progress Report Year 4 (2011). BC Hydro, Environment. Study No. CLBMON-3. 4pp. + appendices.

Pieters, R. and G. Lawrence. 2014. Tributary Water Quality, Kinbasket and Revelstoke Reservoirs, 2012. 43 pp. Appendix 2 in Bray, K.E. 2014. Kinbasket and Revelstoke Reservoirs Ecological Productivity Monitoring. Progress Report Year 5 (2012). BC Hydro, Environment. Study No. CLBMON-3. 4pp. + appendices.

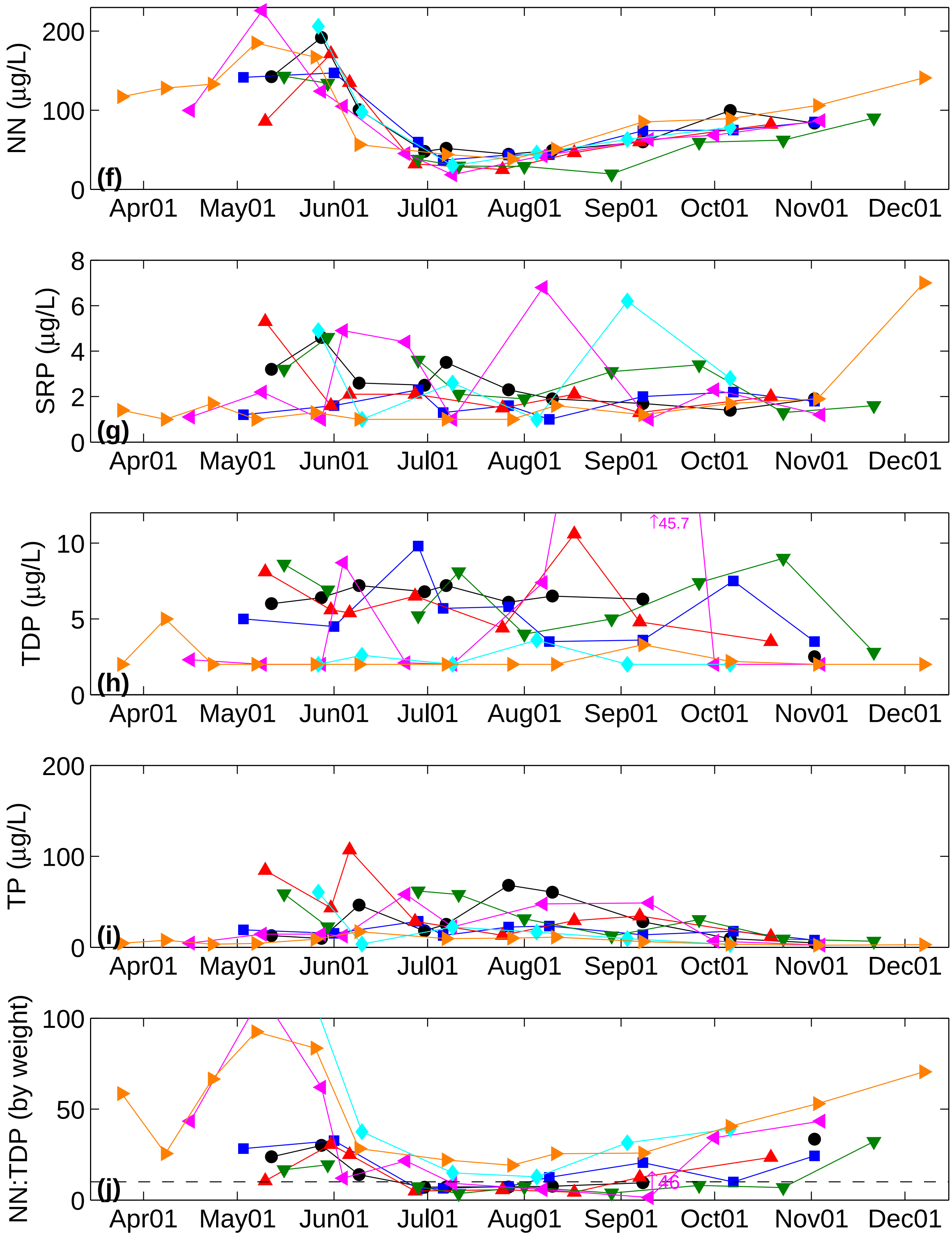
Sebestyen, S. D., E. W. Boyer, J. B. Shanley, C. Kendall, D. H. Doctor, G. R. Aiken, and N. Ohte. 2008. Sources, transformations, and hydrological processes that control stream nitrate and dissolved organic matter concentrations during snowmelt in an upland forest, Water Resour. Res., 44, W12410, doi:10.1029/2008WR006983

Figure 3.1 Columbia R. at Donald: 09, 10, 11, 12, 13, 14 & 15



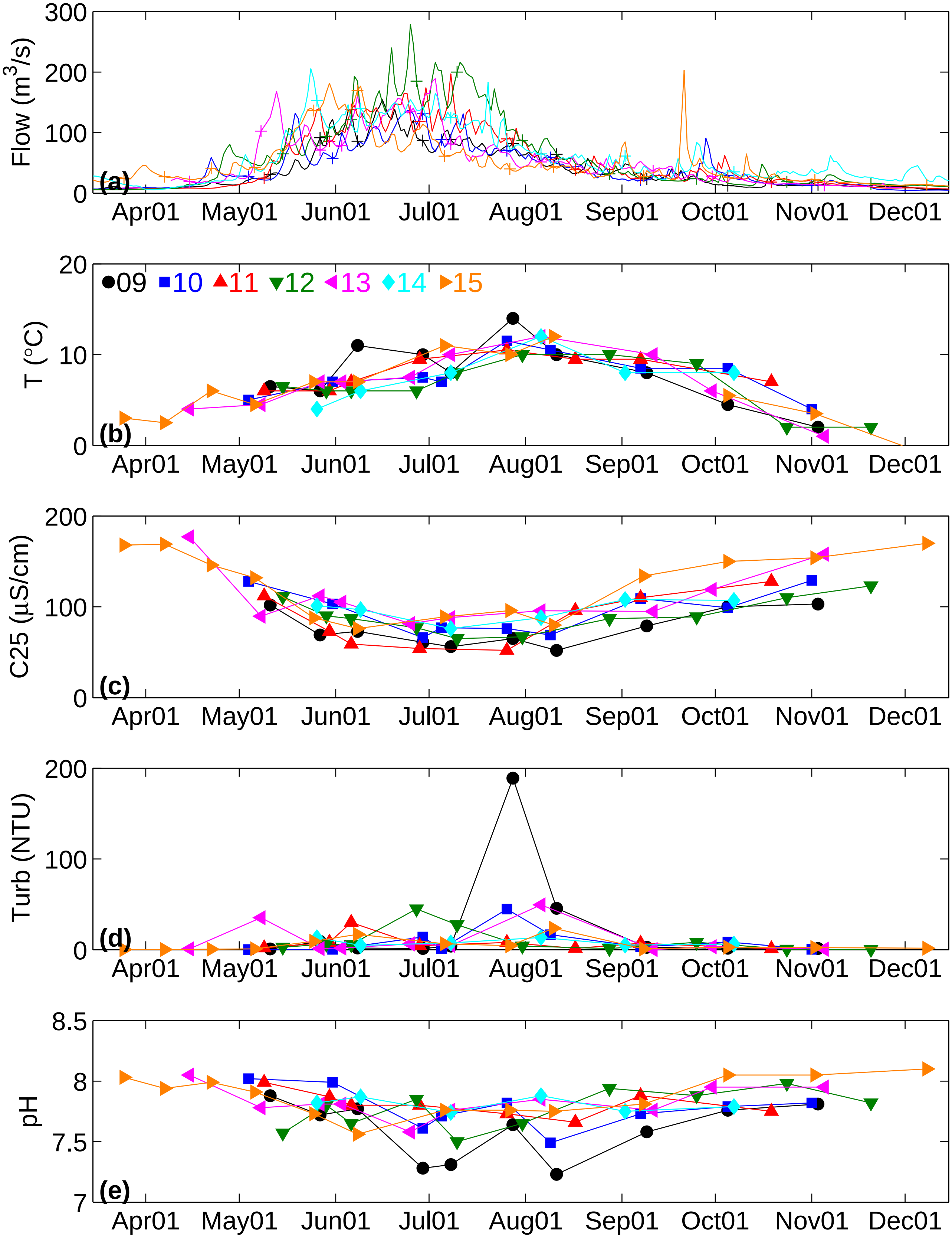
/ocean/rpieters/kr/chem/trib/plot/plotreftrib08to15all.m fig= 1 2017−Jan−17

Figure 3.1 con't Columbia R. at Donald: 09, 10, 11, 12, 13, 14 & 15

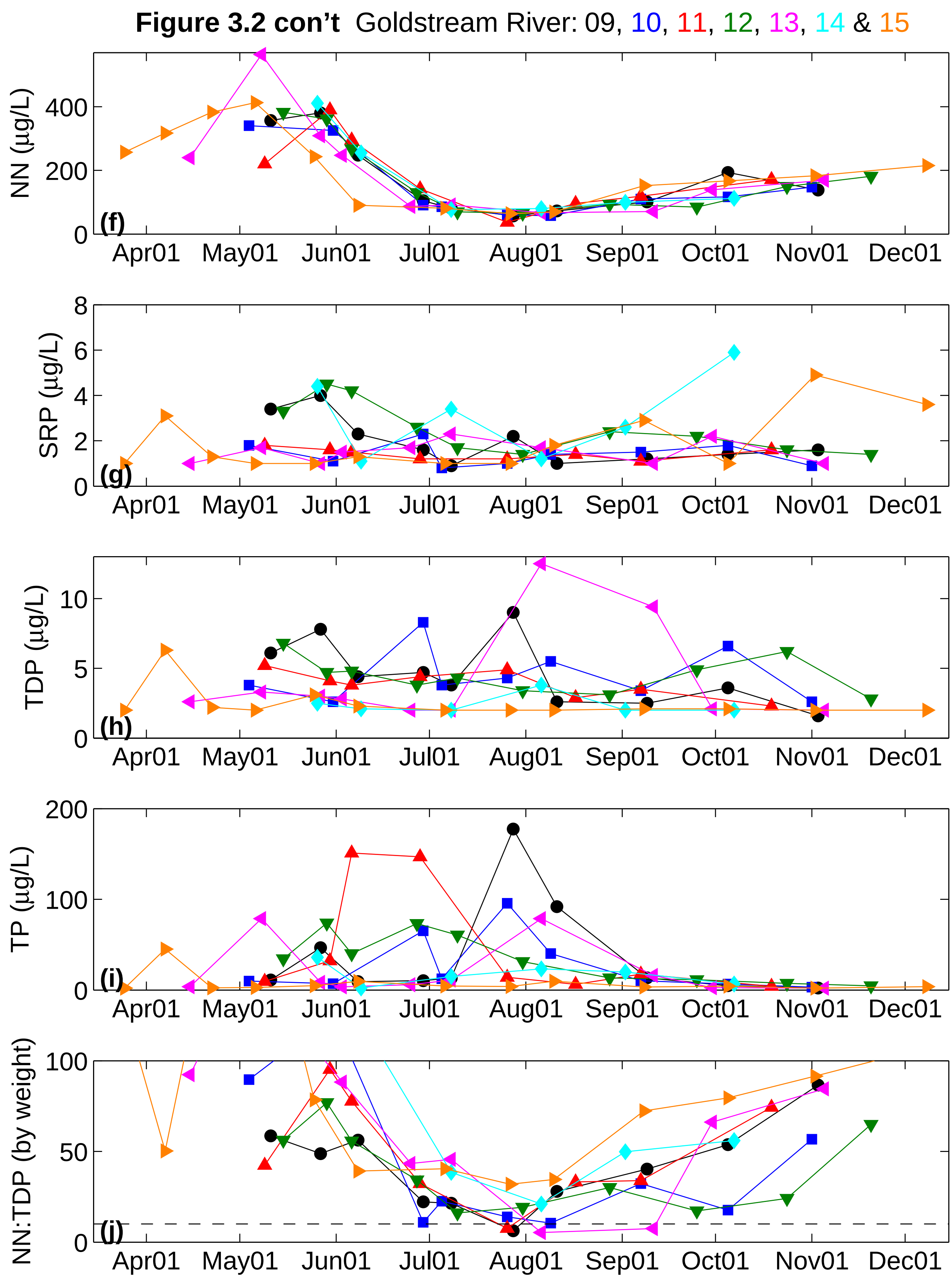


/ocean/rpieters/kr/chem/trib/plot/plotreftrib08to15all.m fig= 6 2017−Jan−17

Figure 3.2 Goldstream River: 09, 10, 11, 12, 13, 14 & 15

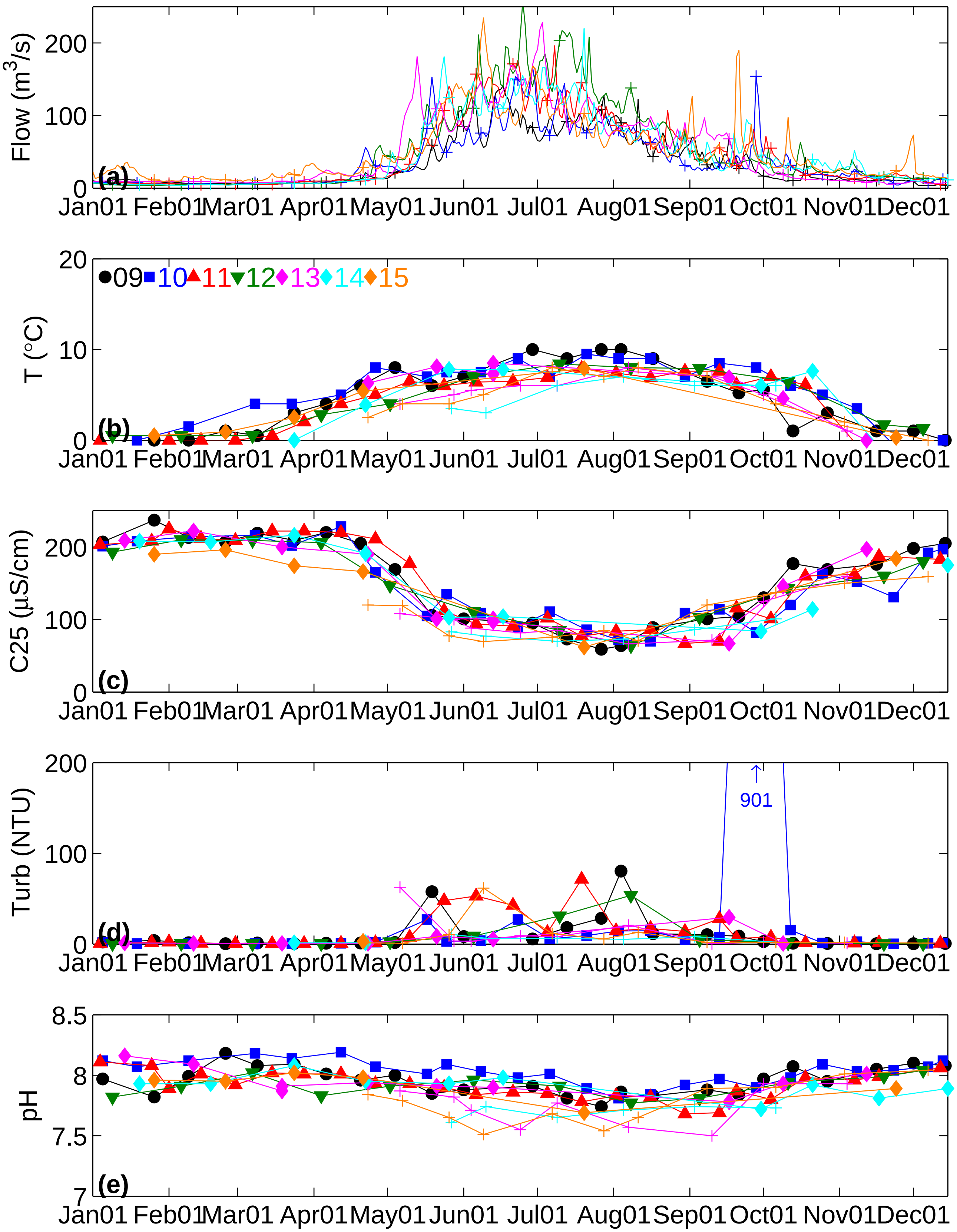


/ocean/rpieters/kr/chem/trib/plot/plotreftrib08to15all.m fig= 2 2017−Jan−17

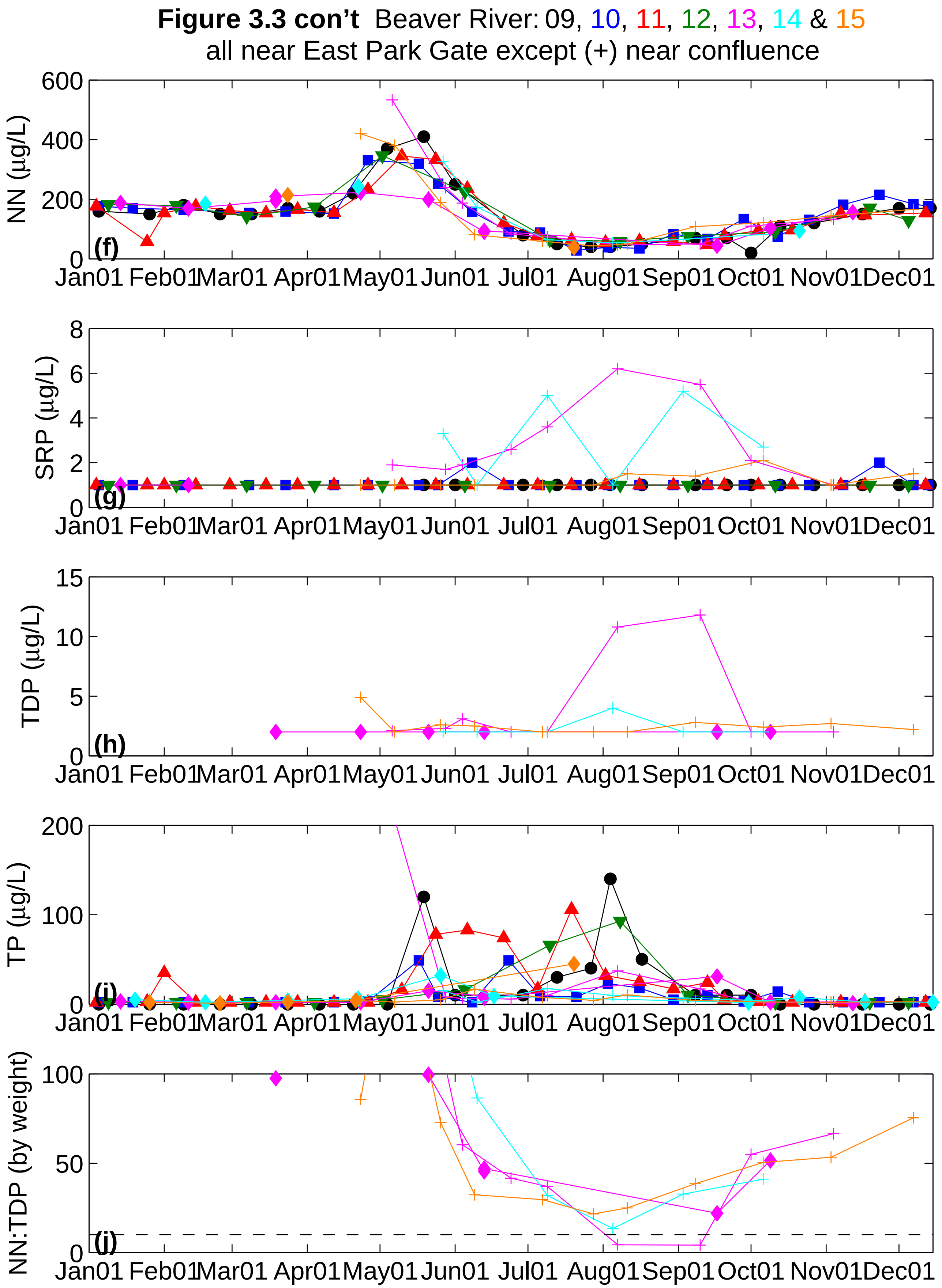


/ocean/rpieters/kr/chem/trib/plot/plotreftrib08to15all.m fig= 7 2017−Jan−17

Figure 3.3 Beaver River: 09, 10, 11, 12, 13, 14 & 15
all near East Park Gate except (+) near confluence

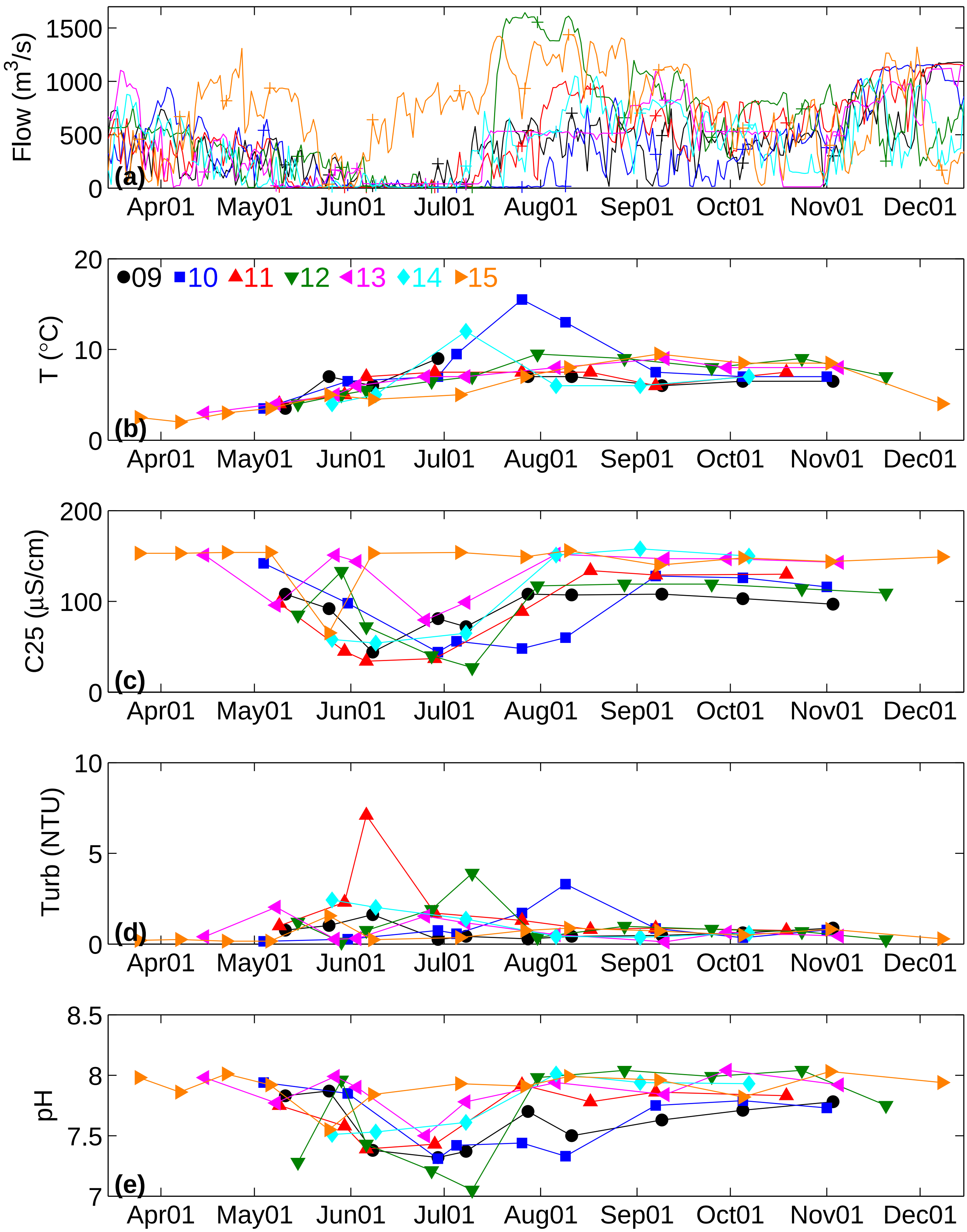


/ocean/rpieters/kr/chem/trib/plot/plotreftrib08to15all.m fig= 3 2017−Jan−17



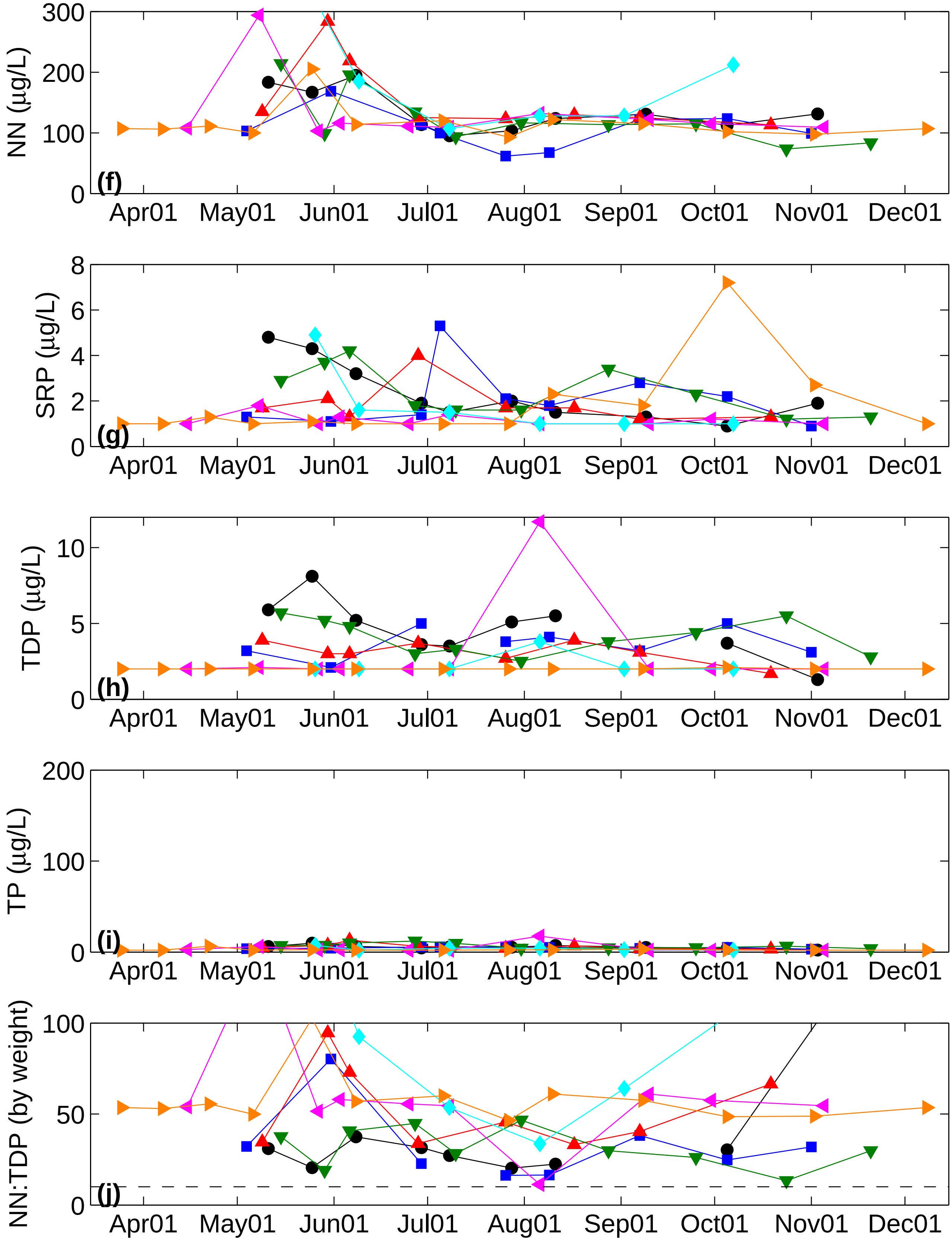
/ocean/rpieters/kr/chem/trib/plot/plotreftrib08to15all.m fig= 8 2017−Jan−17

Figure 3.4 Kinbasket Outflow: 09, 10, 11, 12, 13, 14 & 15



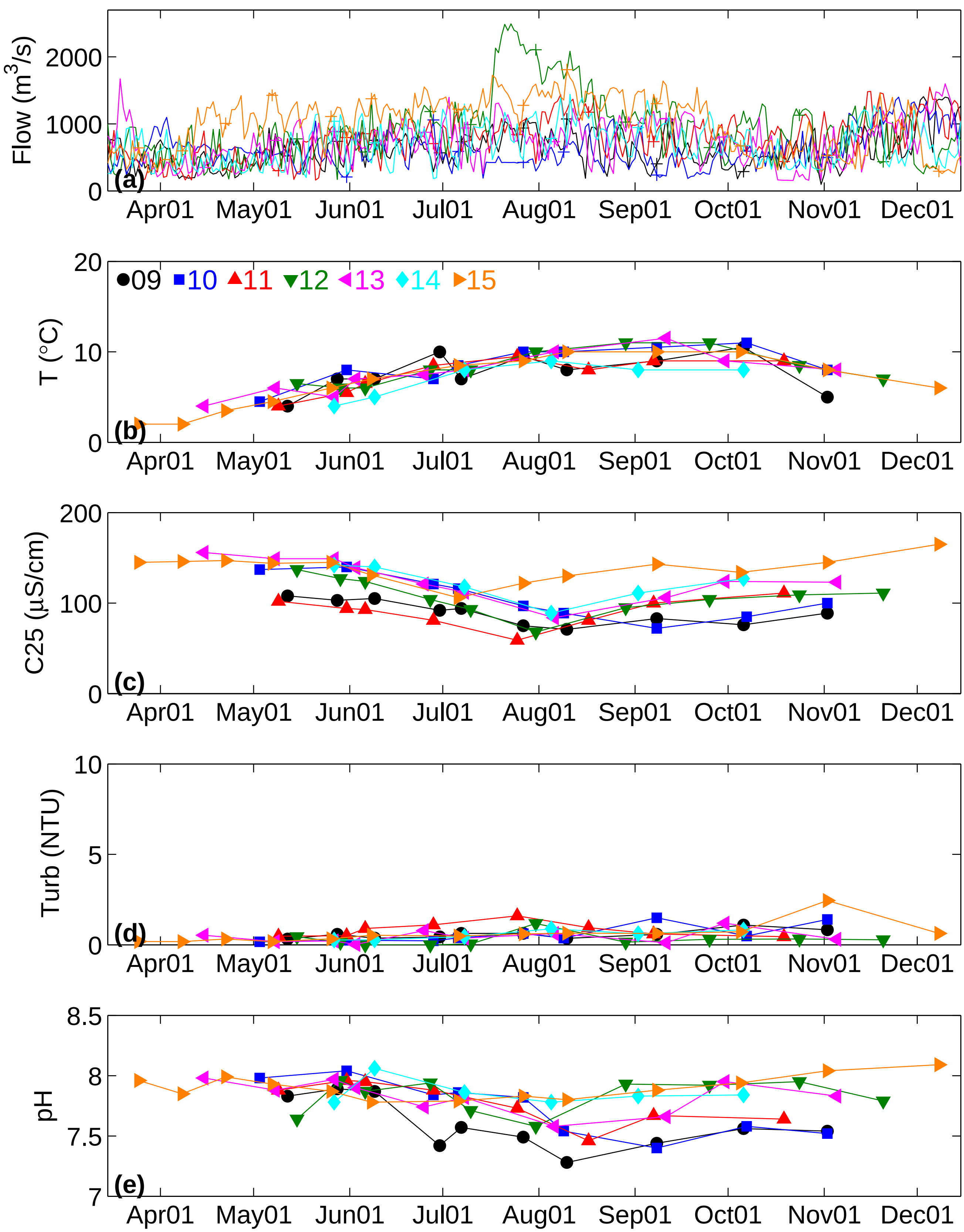
/ocean/rpieters/kr/chem/trib/plot/plotreftrib08to15all.m fig= 4 2017−Jan−17

Figure 3.4 con't Kinbasket Outflow: 09, 10, 11, 12, 13, 14 & 15



/ocean/rpieters/kr/chem/trib/plot/plotreftrib08to15all.m fig= 9 2017−Jan−17

Figure 3.5 Revelstoke Outflow: 09, 10, 11, 12, 13, 14 & 15



/ocean/rpieters/kr/chem/trib/plot/plotreftrib08to15all.m fig= 5 2017−Jan−17

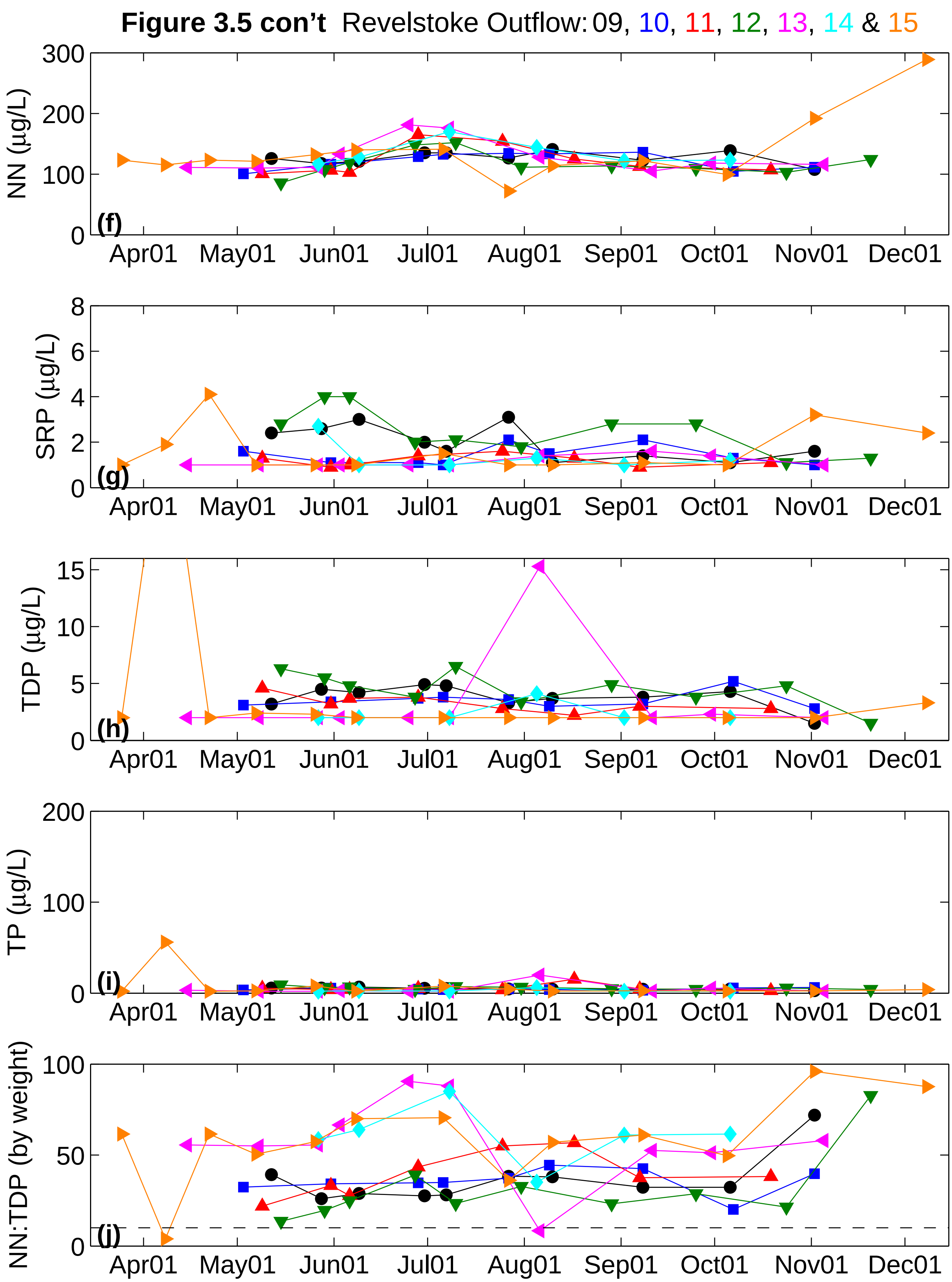
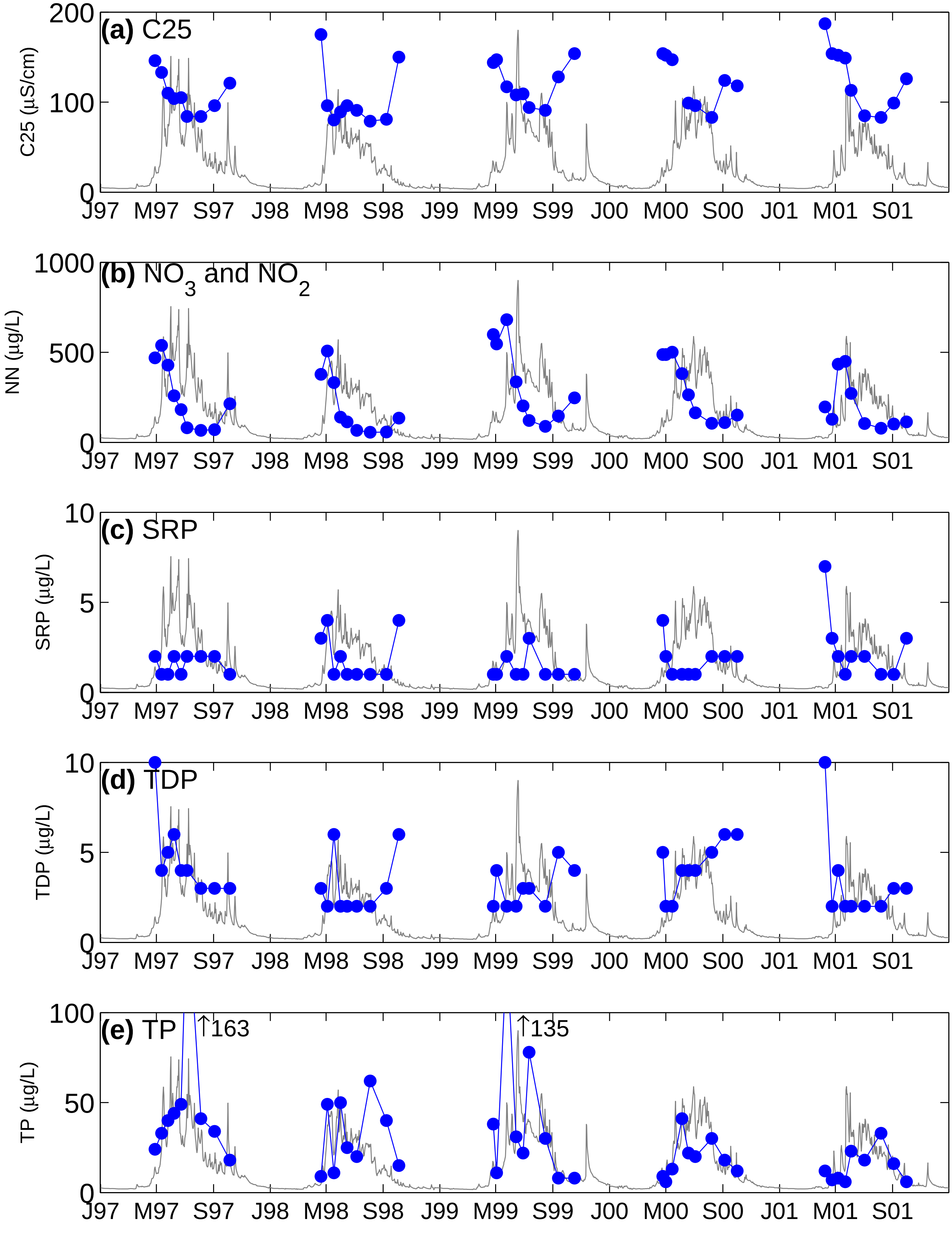


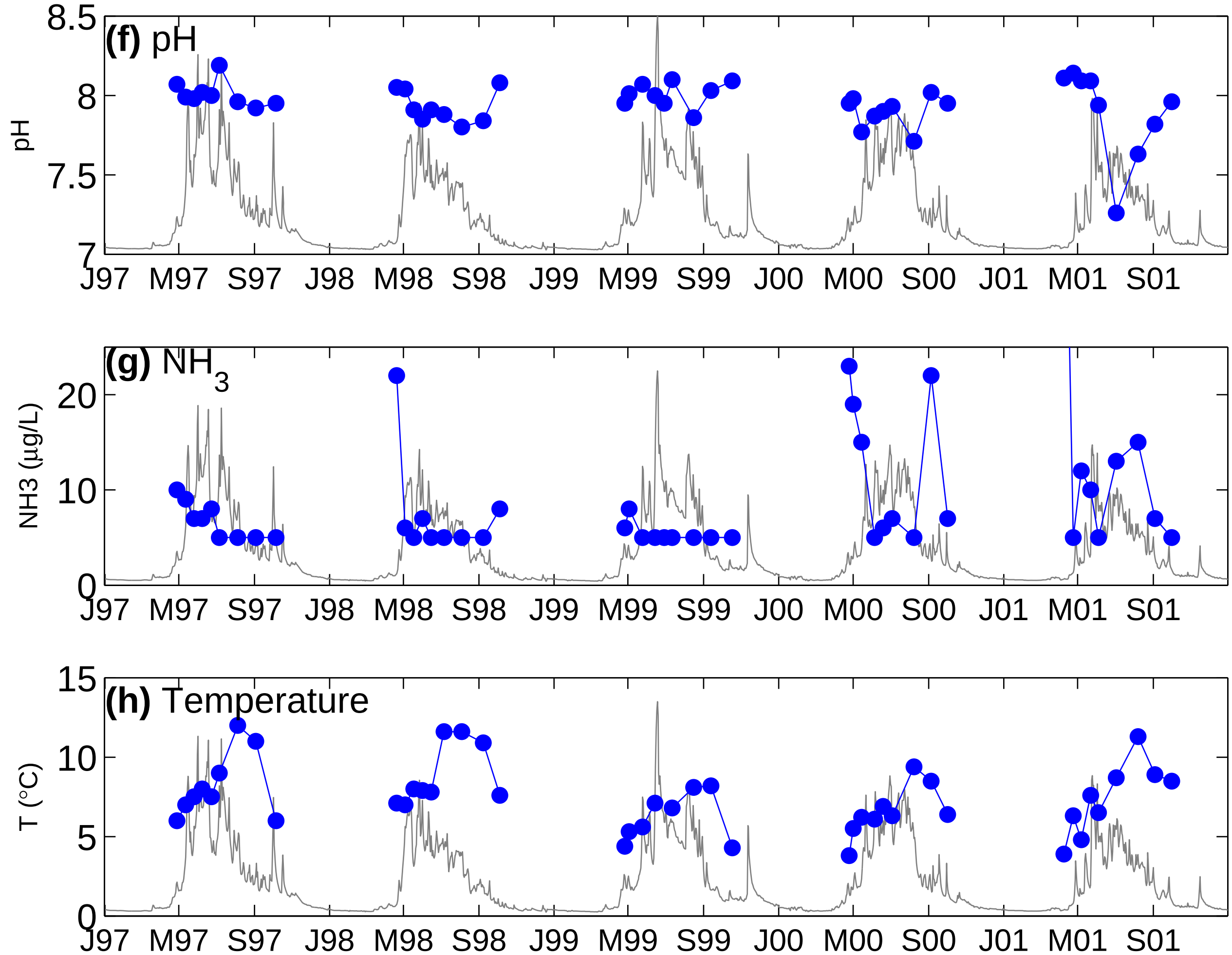
Figure 3.5 con't Revelstoke Outflow: 09, 10, 11, 12, 13, 14 & 15
NN (µg/L)
SRP (µg/L)
TDP (µg/L)
TP (µg/L)
NN:TDP (by weight)
(f)
(g)
(h)
(i)
(j)
Apr01 May01 Jun01 Jul01 Aug01 Sep01 Oct01 Nov01 Dec01

Figure 3.6 Water quality of Illecillewaet River, 1997−2001



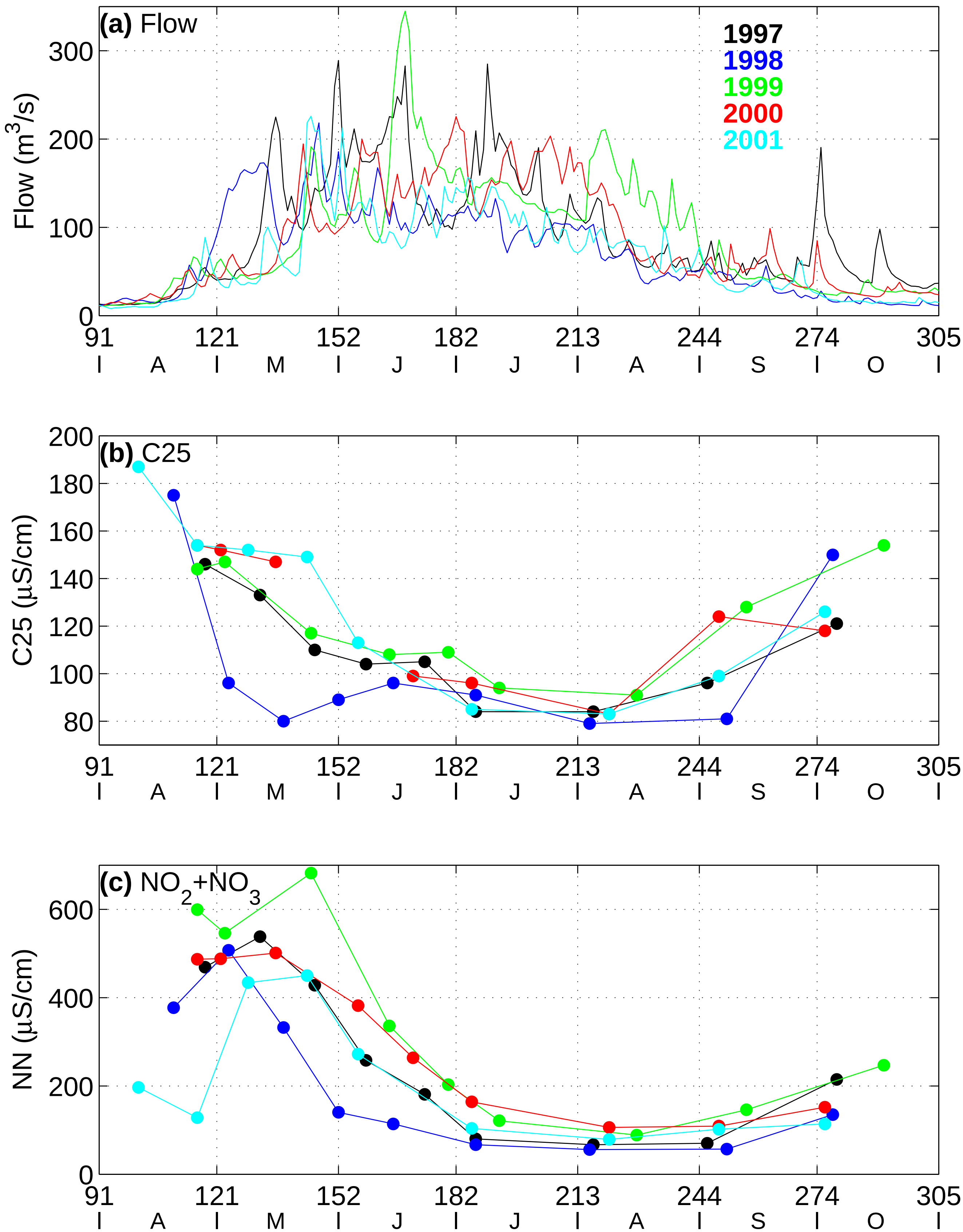
/ocean/rpieters/al97/chem/stream/plotillKINREV10.m fig= 1 2017−Jan−17

Figure 3.6 con’t Water quality of Illecillewaet River, 1997−2001



/ocean/rpieters/al97/chem/stream/plotillKINREV10p2.m fig= 1 2017−Jan−17

Figure 3.7 Flow, C25 and NN in the Illecillewaet River, 1997−2001



/ocean/rpieters/al97/chem/stream/plotillKINREV10p3.m fig= 1 2017−Jan−17

Appendix 1
Summary of Methods, Maxxam Analytics

Samples for NO_3+NO_2, SRP and TDP required filtration. Filtration was done using a 47 mm Swinnex holder with 60 cc syringe. Filters were 0.8 µm glass-fiber (GFF), ashed and washed with distilled/ deionized water before use. The samples for NO_3+NO_2 and SRP were frozen.

A summary of selected laboratory methods were abstracted from Maxxam method summaries as follows.

Phosphorus Standard Methods 22nd Edition, Method 2580 B

Total Phosphorus is the term used to describe the sum of all of the phosphorus present in a sample regardless of form, as measured by the persulphate digestion procedure.

Total orthophosphate is the phosphate that responds to colorimetric tests without preliminary hydrolysis or oxidative digestion of the sample; however a small fraction of condensed phosphates is usually hydrolyzed unavoidably. This form is termed 'reactive phosphorus'.

Phosphorus analysis involves two general steps: a) conversion of the phosphorus form of interest to dissolved orthophosphate, and b) colourimetric determination of dissolved orthophosphate. The sample is divided and the subsamples are prepared for determination of orthophosphate or total phosphate, which are determined sequentially in the Konelab. Ammonium molybdate and antimony potassium tartrate react in an acidic medium with dilute solutions of phosphorus to form an antimony-phospho-molybdate complex. This complex is reduced to an intensely blue coloured complex by ascorbic acid. The colour is proportional to the phosphorus concentration and is measured colorimetrically at 880 nm.

Nitrate and Nitrite Plus Nitrate by Automated Colourimetric Method Standard Methods 22nd Edition, Method 4500-NO3 – I

This method incorporates a split manifold used to determine both nitrite singly and nitrite and nitrate combined. The nitrite (that was originally present, plus reduced nitrate) is determined by diazotizing with sulphanilamide and coupling with N-(1-naphthyl)-ethylenediamine to form an azo dye, measured colourimetrically at 520 nm. For nitrite and nitrate combined, the nitrate in a portion of the sample is quantitatively reduced to nitrite in a reductor column containing amalgamated copperized cadmium filings. The nitrite yielded by the reduction plus the nitrite already present in the sample is then determined as for nitrite. Nitrate is determined by subtraction of the nitrite result from the nitrate + nitrite value.

Conductivity, pH and Alkalinity Standard Methods 22nd Edition, Methods 2510B (Conductivity), 4500B (pH), 2320B (Alkalinity)

Conductivity, pH, and alkalinity are determined sequentially on a sample using a fully automated instrument. Electrometric methods are calibrated daily to account for probe drift and fluctuations in temperature.

A multipoint calibration using standards of known conductivity and the measured cell constant is used to verify system performance. EC is calibrated daily because the cell constant may change over time.

pH measurement is the determination of the activity of the hydrogen ions by potentiometric measurement between electrodes. Combination electrodes, where both electrodes are contained in a single body with a saturated KCl filling solution are most commonly employed. The reference electrode is usually Ag/AgCl or calomel.

Alkalinity is determined by pH end-point titration of a sample aliquot with a standard solution of strong acid. The amount of acid added to the aliquot to bring the pH to 8.3 is used to calculate the phenolphthalein alkalinity. The amount of acid added to the aliquot to bring the pH to 4.5 is used to calculate the total alkalinity. For samples less than 20 mg/L CaCO3, low-level alkalinity is determined by carefully measuring the volume of acid required to lower the total alkalinity end point by exactly 0.3 pH units (doubling the H+ concentration) to pH 4.2.

Turbidity Standard Methods 22nd Edition, Method 2130B
A light source from a tungsten filament lamp is passed through a sample in order to measure the light scattered by the particles suspended in the sample. The intensity of the scattered light is measured by a 90° detector, a forward scatter light detector and a transmitted light detector. The intensity of the scattered light and the transmitted light is mathematically calculated to determine the concentration of the turbidity in the sample.

Correction of Alkalinity data, 2008-2012
Samples analyzed by the Cultus Lake lab were assessed using the low alkalinity method, and these values were given in all previous reports. However, only a few of the samples had alkalinity < 20 mg CaCO3/L for which the low level method is suitable (APHA 1975). The laboratory provided the spreadsheet from which it was possible to re-calculate the appropriate alkalinity, examples of which are shown in Table A1-1. Note that the first end point was not exactly pH 4.5 but ranged from pH 4.3 to 4.7; unfortunately the specific pH end point for each sample was not recorded. The alkalinity was recalculated assuming the end point pH was 4.5. The resulting error was estimated by adding 2/3 of the second end point, which was 0.3 pH units below the first. The resulting errors are less than 10% (Table A1-1). In summary, for alkalinity > 20 mg CaCO3/L, the recalculated values are approximately half of the uncorrected values.

Table A1-1 Example of recalculation of alkalinity, August 5, 2008

Tributary	pH	A or B mls acid to first pH[1]	C mls acid to 0.3 pH lower	N Norm-ality of acid	Low Level Alk [2] mg CaCO3 /L	Regular Alk [3] mg CaCO3 /L	Revised Alk mg CaCO3 /L	Estimated Error %
Beaver R	7.51	3.20	0.170	0.02	62.3	32	32	3.5
Bush R	8.16	8.20	0.290	0.02	161.1	82	82	2.4
Canoe R	6.86	0.70	0.120	0.02	12.8	7	12.8	-
Cummins R	7.68	3.60	0.150	0.02	70.5	36	36	2.8
Dave Henry Cr	7.30	1.80	0.160	0.02	34.4	18	18	5.9
Foster Cr	7.05	1.10	0.150	0.02	20.5	11	11	9.1
Gold R	7.71	3.00	0.200	0.02	58.0	30	30	4.4
Hugh Allen Cr	7.44	2.50	0.170	0.02	48.3	25	25	4.5
Kinbasket R	8.03	5.90	0.220	0.02	115.8	59	59	2.5
Molson Cr	7.81	4.30	0.170	0.02	84.3	43	43	2.6
Ptarmigan Cr	7.28	1.70	0.160	0.02	32.4	17	17	6.3
Sullivan R	8.15	6.50	0.320	0.02	126.8	65	65	3.3
Windy Cr	7.31	1.60	0.150	0.02	30.5	16	16	6.3
Wood R	8.10	6.90	0.250	0.02	135.5	69	69	2.4

All sample volumes V = 100 mL.
(1) First pH = 4.5 (4.3 - 4.7)
(2) Low level alkalinity ((2*B-C)*N*50000)/V
(3) Regular alkalinity (A*N*50000)/V

Appendix 2
Tributaries

Table A2-1 Tributaries to Kinbasket Reservoir

Name	**Lat (N)/Long (W)**	**Drainage Area (1)** (km^2)
Columbia R. at Donald Station	51° 29.0 117° 10.5	9710
Waitabit Creek (new in 2013)	51°30.201 117°11.796	*~400*
Bluewater Creek (new in 2013)	51°30.164 117°13.571	*~400*
Quartz Creek (new in 2013)	51°31.310 117°23.947	*~100*
Beaver River at confluence during low pool, ~800 m below confluence at full pool (accessed by helicopter during 2013 survey)	51°32.105 117°25.592	
Beaver River near confluence at full pool (Kinbasket Lake Resort)	51°31.668 117°26.012	
Beaver River at WSC gauge 08NB019 (just above railroad bridge and ~2.5 km above confluence at full pool)	51° 30.58 117° 27.70	1150
Beaver River above Cupola Cr (near Roger's Road bridge and ~6 km above confluence at full pool)	51°29.264 117°29.503	
Beaver River near East Park Gate (at Highway 1 bridge and ~18 km above confluence at full pool)(2)	51°23 / 117°27	*~600*
Gold River	51° 41.5 117° 42.5	542
Bush Arm		
Bush River	51° 47.5 117° 22.4	1032
Prattle Creek	51° 47.3 117° 25.4	199
Chatter Creek	51° 47.1 117° 26.3	102
Succour Creek (new in 2013)	51°45.014 117°35.631	*~50*
Columbia Reach		
Windy Creek	51° 52.5 118° 01.2	243
Sullivan River	51° 57.2 117° 51.4	593
Kinbasket River	51° 58.5 117° 57.5	*160*
Cummins	52° 03.1 118° 09.5	268
Wood Arm		
Wood River	52° 12.2 118° 10.3	451
Canoe Reach		
Canoe River	52° 46.4 119° 09.6	611

Dave Henry Creek	52° 44.4 119° 05.6	96
Yellowjacket Creek	52° 42.1 119° 03.1	104
Bulldog Creek	52° 38.4 118° 58.5	107
Ptarmigan Creek	52° 35.0 118° 39.5	295
Hugh Allan Creek	52° 26.4 118° 39.5	626
Foster Creek	52° 15.2 118° 38.1	187
Dawson Creek	52° 15.6 118° 29.5	108
Molson Creek	52° 10.4 118° 21.8	77

[1] From Water Survey Canada and BC Hydro; estimated values in italics

[2] Beaver River near the mouth (WSC 08NB019 at 51° 30.58 N and 117° 27.70 W) drains 1,150 km^2. Tributary sampling by Environment Canada was upstream at Beaver River near East Park Gate (BC08NB00002) with approximately half the drainage.

Table A2-2 Tributaries to Revelstoke Reservoir

Name	**Lat Long**	**Drainage Area**[2] (km²)
Upper		
Columbia River at Mica (Kinbasket Reservoir/Mica Dam Outflow)	52° 02.6 118° 35.3	21500[1]
Nagle Creek	52° 03.1 118° 35.4	157
Soards Creek	52° 03.5 118° 37.3	161
Mica Creek	52° 00.4 118° 34.0	84
Pat Creek (new in 2013)	51°57.0 118°34.7	*200*
Pitt Creek	51° 57.3 118° 33.5	*5*
Birch Creek	51° 55.2 118° 33.5	27
Bigmouth Creek	51° 49.4 118° 32.4	588
Scrip Creek	51° 49.4 118° 39.2	160
Horne Creek	51° 46.4 118° 41.2	121
Hoskins Creek	51° 41.6 118° 40.1	101
Goldstream River	51° 40.0 118° 38.6	953
Kirbyville Creek	51° 39.1 118° 38.3	117
Lower		
Downie Creek	51° 30.1 118° 22.1	657
Bourne Creek	51° 23.5 118° 27.5	69
Big Eddy Creek	51° 19.5 118° 23.2	57
Carnes Creek	51° 18.1 118° 17.1	188
Martha Creek	51° 09.2 118° 12.0	13
Columbia R. above Jordan	51° 01.0 118° 13.3	26700[1]

[1] From Water Survey Canada
[2] Estimated values in italics

Appendix 3
Tributary Data

Appendix 3.1 Reference Tributaries

		Date	pH	Cond	NN	SRP	TDP	TP	TP Turb	TPc[1]	Turb	Alk [2]	T	Color [3]
				(µS/cm)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(NTU)	(mgCaCO3/L)	(°C)	
Columbia at Donald	1	06/24/2008	8.06	160	63.2	2.7	10.7	43.0	25.5	17.5	19.2	83	11.5	B
Columbia at Donald	1	05/12/2009	8.26	220	142.3	3.2	6	12.8	3.1	9.7	6.08	132	10.0	TM
Columbia at Donald	1	05/28/2009	8.14	156	191.9	4.6	6.4	9.7	3.7	6	28	100	12.0	TB
Columbia at Donald	1	06/09/2009	8.05	135	100.6	2.6	7.2	46.5	NaN	NaN	15.8	83	11.0	TB
Columbia at Donald	1	06/30/2009	7.78	135	48	2.5	6.8	18	3.4	14.6	3.8	79.2	14.0	TB
Columbia at Donald	1	07/07/2009	7.83	130	51.8	3.5	7.2	25.4	5.8	19.6	19.2	77	15.0	MB
Columbia at Donald	1	07/27/2009	7.97	112	44.3	2.3	6.1	68.3	41.6	26.7	59	75.6	17.5	TM
Columbia at Donald	1	08/10/2009	7.77	115	49.1	1.9	6.5	60.6	33.8	26.8	38.1	73	15.0	TM
Columbia at Donald	1	09/08/2009	7.83	127	60	1.7	6.3	28	17	11	29.6	78.4	11.0	MB
Columbia at Donald	1	10/06/2009	8	164	99.6	1.4	NaN	9.5	5.8	3.7	3.31	103.5	5.5	C
Columbia at Donald	1	11/02/2009	8.06	190	83.7	1.9	2.5	4.8	1.9	2.9	1.7	114.2	3.0	C
Columbia at Donald	1	05/03/2010	8.25	244	141.5	1.2	5.0	19.2	6.7	12.5	2.56	115	8.0	MG
Columbia at Donald	1	06/01/2010	8.19	197	147.1	1.6	4.5	15.3	<0.1	15.2	3.35	93.4	9.0	TGB
Columbia at Donald	1	06/28/2010	8.08	151	59.7	2.3	9.8	28.7	12.3	16.4	11.55	77.5	12.0	TB
Columbia at Donald	1	07/06/2010	8.04	169	36.8	1.3	5.7	12.9	2.9	10.1	2.72	79.5	11.5	TGB
Columbia at Donald	1	07/27/2010	8.17	154	43.3	1.6	5.8	22.3	12.0	10.4	18.15	74	15.0	M
Columbia at Donald	1	08/09/2010	8.02	144	43.7	1.0	3.5	23.4	17.2	6.3	20.05	70.1	14.0	TB
Columbia at Donald	1	09/08/2010	8.09	195	74.0	2.0	3.6	13.7	7.1	6.6	10.59	95.5	10.5	T
Columbia at Donald	1	10/07/2010	8.02	182	74.9	2.2	7.5	17.8	9.0	8.7	12.45	91.5	7.5	TGB
Columbia at Donald	1	11/02/2010	8.10	227	85.1	1.8	3.5	7.9	3.8	4.1	2.11	113	4.0	C
Columbia at Donald	1	05/10/2011	8.26	218	85.9	5.3	8.1	84.5	65.5	19.0	52.5	145	9.5	TB
Columbia at Donald	1	05/31/2011	8.14	141	171.4	1.6	5.6	43.3	17.7	25.6	31.0	102	9.0	TB
Columbia at Donald	1	06/06/2011	8.19	139	135.0	2.1	5.4	107.1	73.5	33.6	45.0	106	11.0	TB
Columbia at Donald	1	06/27/2011	8.01	122	32.1	2.1	6.5	28.5	3.5	25.1	13.5	86	13.0	TB
Columbia at Donald	1	07/25/2011	8.04	108	25.0	1.5	4.4	13.1	3.5	9.6	15.0	78.6	15.0	TB
Columbia at Donald	1	08/17/2011	7.93	163	46.2	2.1	10.6	29.4	9.7	19.7	17.5	79.5	11.0	TB
Columbia at Donald	1	09/07/2011	8.12	195	60.0	1.3	4.8	34.4	8.7	25.6	9.8	95.5	11.0	TB
Columbia at Donald	1	10/19/2011	8.12	231	82.3	2.0	3.5	11.9	**	NaN	5.9	108.5	4.0	TB
Columbia at Donald	1	05/15/2012	8.14	243	143.0	3.2	8.6	58.7	16.4	42.3	39.0	125.5	10.0	M
Columbia at Donald	1	05/29/2012	8.21	213	134.0	4.6	6.9	22.4	2.3	20.0	12.5	112.5	10.0	TB
Columbia at Donald	1	06/05/2012	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	n/a
Columbia at Donald	1	06/27/2012	8.13	171	38.0	3.6	5.2	61.8	21.5	40.3	55.0	112.2	10.5	TB
Columbia at Donald	1	07/10/2012	8.11	162	29.3	2.1	8.1	58.1	23.8	34.3	110.0	114.9	14.0	TB
Columbia at Donald	1	07/31/2012	8.07	150	28.9	1.9	4.0	31.3	17.6	13.7	29.1	87.9	15.0	TB
Columbia at Donald	1	08/28/2012	8.14	160	19.3	3.1	5.0	12.5	6.3	6.1	14.0	90.7	13.0	LTB
Columbia at Donald	1	09/25/2012	8.19	188	59.4	3.4	7.4	30.5	23.0	7.4	56.6	108.5	10.0	TB
Columbia at Donald	1	10/22/2012	8.19	206	62.1	1.3	9.0	9.0	1.6	7.4	3.18	109	4.0	C
Columbia at Donald	1	11/20/2012	8.09	236	90.2	1.6	2.8	6.6	1.7	4.9	2.78	124	1.0	C
Columbia at Donald	1	04/16/2013	8.23	344	99.8	1.1	2.3	4.7	NaN	NaN	2.6	145	5.0	GC
Columbia at Donald	1	05/09/2013	8.22	258	226	2.2	<2.00	14.4	NaN	NaN	45.2	114	10.0	B
Columbia at Donald	1	05/28/2013	8.11	221	124	1.0	<2.00	14.4	NaN	NaN	5.46	94	10.0	MG
Columbia at Donald	1	06/04/2013	8.02	222	105	4.9	8.7	12.4	NaN	NaN	8.49	95.8	11.0	GB

		Date	pH	Cond	NN	SRP	TDP	TP	TP Turb	TPc[1]	Turb	Alk [2]	T	Color [3]
Columbia at Donald	1	06/24/2013	7.92	186	45.3	4.4	2.1	58.3	NaN	NaN	28.4	79.7	13.0	B
Columbia at Donald	1	07/09/2013	7.99	179	18.5	<1.00	<2.00	22.5	NaN	NaN	19.7	77.8	15.0	B
Columbia at Donald	1	08/07/2013	8.03	174	42.5	6.8	7.4	47.6	NaN	NaN	44	74.6	14.0	MB
Columbia at Donald	1	09/10/2013	7.88	176	62.9	<1.00	45.7	48.8	NaN	NaN	0.13	71.1	12.0	B
Columbia at Donald	1	10/01/2013	8.16	245	68.5	2.3	<2.00	6.9	NaN	NaN	11.1	97.8	8.0	B
Columbia at Donald	1	11/04/2013	8.15	282	86.8	1.2	<2.00	2.4	NaN	NaN	1.74	112	1.5	C
Columbia at Donald	1	05/27/2014	8.08	201	206.0	4.9	<2.00	60.5	NaN	NaN	46.1	87.9	8.0	B
Columbia at Donald	1	06/10/2014	8.15	203	97.6	<1.00	3.5*	2.6	NaN	NaN	29.8	87.3	10.0	B
Columbia at Donald	1	07/09/2014	7.96	172	29.9	2.6	<2.00	22.3	NaN	NaN	11.6	72.0	15.0	B
Columbia at Donald	1	08/05/2014	8.06	176	45.8	<1.00	3.6	16.7	NaN	NaN	9.3	72.0	14.0	B
Columbia at Donald	1	09/03/2014	8.04	202	62.9	6.2	<2.00	9.5	NaN	NaN	13.4	78.5	10.0	MG
Columbia at Donald	1	10/06/2014	8.04	242	78.2	2.8	<2.00	3.0	NaN	NaN	2.89	93.8	7.0	GC
Columbia at Donald	1	03/25/2015	8.15	328	117.0	1.4	<2.00	4.4	NaN	NaN	1.91	136.0	3.0	MG
Columbia at Donald	1	04/08/2015	8.15	329	128.0	<1.00	5.0	7.7	NaN	NaN	1.33	131.0	3.5	GC
Columbia at Donald	1	04/23/2015	8.24	319	133.0	1.7	<2.00	3.4	NaN	NaN	2.43	135.0	8.0	GC
Columbia at Donald	1	05/07/2015	8.16	277	185.0	<1.00	<2.00	4.2	NaN	NaN	2.01	112.0	8.5	GB
Columbia at Donald	1	05/26/2015	8.03	187	167.0	1.3	<2.00	8.8	NaN	NaN	28.9	80.9	9.0	B
Columbia at Donald	1	06/09/2015	7.92	181	56.6	<1.00	<2.00	17.1	NaN	NaN	66.2	76.1	12.0	B
Columbia at Donald	1	07/07/2015	7.98	171	44.0	<1.00	2.0	9.5	NaN	NaN	15.4	68.7	15.5	B
Columbia at Donald	1	07/28/2015	7.93	165	38.3	<1.00	<2.00	10.0	NaN	NaN	16.9	66.6	12.0	GB
Columbia at Donald	1	08/11/2015	8.01	176	50.9	1.6	<2.00	11.2	NaN	NaN	21.1	72.0	14.5	GB
Columbia at Donald	1	09/08/2015	8.10	229	85.2	1.2	3.3	6.3	NaN	NaN	5.39	87.9	7.0	MG
Columbia at Donald	1	10/06/2015	8.09	248	89.3	1.7	2.2	3.4	NaN	NaN	4.35	93.9	7.0	M
Columbia at Donald	1	11/03/2015	8.17	272	106.0	1.9	<2.00	2.3	NaN	NaN	2.05	108.0	3.0	GC
Columbia at Donald	1	12/07/2015	8.26	305	141.0	7.0	<2.00	2.9	NaN	NaN	2.37	128.0	-1.0	C 3/4F
Columbia at Mica Outflow	2	06/24/2008	7.80	108	114.0	2.9	5.8	8.7	0.9	7.8	0.74	52	7.0	n/a
Columbia at Mica Outflow	2	05/11/2009	7.83	108	183.2	4.8	6.1*	5.9	0.1	5.9	0.77	58	3.5	C
Columbia at Mica Outflow	2	05/25/2009	7.87	92	166.9	4.3	8.1	9.8	0.1	9.8	1.02	55	7.0	C
Columbia at Mica Outflow	2	06/08/2009	7.38	44	194.6	3.2	5.2	6.2	0.1	6.2	1.62	22	6.0	TB
Columbia at Mica Outflow	2	06/29/2009	7.32	81	113.6	1.9	3.6	4.5	0.1	4.5	0.25	48.1	9.0	C
Columbia at Mica Outflow	2	07/08/2009	7.37	72	95.1	1.5	3.5	5.7	0.1	5.7	0.42	44	NaN	n/a
Columbia at Mica Outflow	2	07/28/2009	7.7	108	103.3	2	5.1	5.4	0.1	5.4	0.29	71	7.0	C
Columbia at Mica Outflow	2	08/11/2009	7.5	107	123.6	1.5	5.5	7.1	0.1	7.1	0.42	70	7.0	C
Columbia at Mica Outflow	2	09/09/2009	7.63	108	130.7	1.3	NaN	5.1	0.1	5.1	0.48	70	6.0	C
Columbia at Mica Outflow	2	10/05/2009	7.71	103	112.5	0.9	4*	3.7	0.3	3.4	0.62	65.9	6.5	C
Columbia at Mica Outflow	2	11/03/2009	7.78	97	131.3	1.9	1.3	2.1	0.1	2.1	0.88	62	6.5	C
Columbia at Mica Outflow	2	05/04/2010	7.94	142	103.0	1.3	3.2	3.7	<0.1	3.6	0.15	69	3.5	C
Columbia at Mica Outflow	2	05/31/2010	7.85	98	168.6	1.1	2.1	4.2	<0.1	4.1	0.27	44.1	6.5	C
Columbia at Mica Outflow	2	06/29/2010	7.31	44	113.6	1.4	5.0	5.6	1.4	4.2	0.75	17.7	7.0	T
Columbia at Mica Outflow	2	07/05/2010	7.42	56	99.5	5.3	**	5.7	<0.1	5.6	0.57	23	9.5	C
Columbia at Mica Outflow	2	07/26/2010	7.44	48	61.8	2.1	3.8	5.7	1.7	4.1	1.71	20	15.5	C
Columbia at Mica Outflow	2	08/09/2010	7.33	60	67.5	1.8	4.1	5.1	0.8	4.3	3.30	26.4	13.0	C
Columbia at Mica Outflow	2	09/07/2010	7.75	128	122.2	2.8	3.2	4.0	<0.1	3.9	0.86	64.7	7.5	C
Columbia at Mica Outflow	2	10/05/2010	7.79	126	123.7	2.2	5.0	5.2	<0.1	5.1	0.35	64	7.0	C
Columbia at Mica Outflow	2	11/01/2010	7.73	116	99.0	0.9	3.1	3.1	<0.1	3.0	0.78	60	7.0	C

		Date	pH	Cond	NN	SRP	TDP	TP	TP Turb	TPc[1]	Turb	Alk [2]	T	Color [3]
Columbia at Mica Outflow	2	05/09/2011	7.75	98	135.0	1.7	3.9	4.8	<0.1	4.7	1.00	60.9	4.0	C
Columbia at Mica Outflow	2	05/30/2011	7.58	45	283.9	2.1	3.0	7.5	2.4	5.1	2.30	26	5.0	TLB
Columbia at Mica Outflow	2	06/06/2011	7.39	34	218.6	1.3	3.0	12.9	4.2	8.7	7.10	20	7.0	TSM
Columbia at Mica Outflow	2	06/28/2011	7.43	37	125.2	4.0	3.7	6.2	<0.1	6.1	1.70	22.2	7.5	C
Columbia at Mica Outflow	2	07/26/2011	7.92	89	123.3	1.7	2.7	4.0	0.5	3.5	1.30	61.4	7.5	C
Columbia at Mica Outflow	2	08/17/2011	7.78	134	129.5	1.7	3.9	6.9	0.4	6.5	0.80	66	7.5	C
Columbia at Mica Outflow	2	09/07/2011	7.86	129	125.1	1.2	3.7*	3.1	**	NaN	0.88	63.5	6.0	C
Columbia at Mica Outflow	2	10/19/2011	7.83	130	113.1	1.3	1.7	3.4	<0.1	3.3	0.75	63	7.5	C
Columbia at Mica Outflow	2	05/14/2012	7.28	85	213.9	2.9	5.7	7.2	1.1	6.1	1.20	37.3	4.0	C
Columbia at Mica Outflow	2	05/28/2012	7.96	133	98.9	3.7	5.2	7.3	1.0	6.3	0.10	53.65	5.0	C
Columbia at Mica Outflow	2	06/05/2012	7.43	72	195.5	4.2	4.8	9.9	1.9	8.0	0.75	33.25	5.5	TB
Columbia at Mica Outflow	2	06/26/2012	7.21	40	134.6	1.8	3.0	12.0	5.2	6.8	1.90	17.5	6.5	TB
Columbia at Mica Outflow	2	07/09/2012	7.05	27	93.5	1.6	3.3	9.6	2.3	7.3	3.90	11.1	7.0	TB
Columbia at Mica Outflow	2	07/30/2012	7.98	117	116.5	1.6	2.5	4.3	<0.1	4.2	0.37	64.5	9.5	C
Columbia at Mica Outflow	2	08/27/2012	8.04	119	113.5	3.4	3.8	4.6	1.9	2.7	0.98	67.7	9.0	C
Columbia at Mica Outflow	2	09/24/2012	7.99	119	114.9	2.3	4.4	4.8	<0.1	4.7	0.81	64.2	8.0	C
Columbia at Mica Outflow	2	10/23/2012	8.04	114	73.5	1.2	6.5*	5.5	<0.1	5.4	0.69	61.3	9.0	C
Columbia at Mica Outflow	2	11/19/2012	7.75	109	83.5	1.3	2.8	3.8	<0.1	3.7	0.24	60.2	7.0	C
Columbia at Mica Outflow	2	04/15/2013	7.98	151	108	<1.00	2.0	2.9	NaN	NaN	0.4	66	3.0	C
Columbia at Mica Outflow	2	05/08/2013	7.77	95.9	294	1.8	2.1	6.1	NaN	NaN	2.03	40.2	4.0	LB
Columbia at Mica Outflow	2	05/27/2013	7.99	151	103	<1.00	2.4*	<2.00	NaN	NaN	0.27	62.9	5.0	C
Columbia at Mica Outflow	2	06/03/2013	7.9	144	116	1.3	<2.00	2.6	NaN	NaN	0.3	59.6	6.0	C
Columbia at Mica Outflow	2	06/25/2013	7.5	79.4	111	<1.00	<2.00	<2.00	NaN	NaN	1.54	29	7.0	C
Columbia at Mica Outflow	2	07/08/2013	7.78	99	109	1.4	<2.00	<2.00	NaN	NaN	1.17	39.4	7.0	C
Columbia at Mica Outflow	2	08/06/2013	7.94	152	132	1.0	11.7	17.5	NaN	NaN	0.51	66.4	8.0	C
Columbia at Mica Outflow	2	09/10/2013	7.84	147	122	<1.00	<2.00	<2.00	NaN	NaN	0.12	62.8	9.0	C
Columbia at Mica Outflow	2	09/30/2013	8.04	147	115	1.2	<2.00	<2.00	NaN	NaN	0.65	62.8	8.0	C
Columbia at Mica Outflow	2	11/05/2013	7.92	143	109	<1.00	<2.00	<2.00	NaN	NaN	0.44	58.9	8.0	C
Columbia at Mica Outflow	2	05/26/2014	7.51	58	319.0	4.9	<2.00	7.4	NaN	NaN	2.43	17.2	4.0	C
Columbia at Mica Outflow	2	06/09/2014	7.53	54	185.0	1.6	<2.00	<2.00	NaN	NaN	2.02	16.7	5.0	LB
Columbia at Mica Outflow	2	07/08/2014	7.61	65	107.0	1.5	<2.00	4.2	NaN	NaN	1.38	25.5	12.0	C
Columbia at Mica Outflow	2	08/06/2014	8.01	151	128.0	<1.00	3.8	4.2	NaN	NaN	0.42	63.8	6.0	C
Columbia at Mica Outflow	2	09/02/2014	7.94	158	128.0	<1.00	<2.00	2.6	NaN	NaN	0.38	64.0	6.0	C
Columbia at Mica Outflow	2	10/07/2014	7.93	150	212.0	<1.00	<2.00	<2.00	NaN	NaN	0.59	63.1	7.0	C
Columbia at Mica Outflow	2	03/25/2015	7.98	153.0	107.0	<1.00	<2.00	<2.00	NaN	NaN	0.20	63.0	2.5	C
Columbia at Mica Outflow	2	04/07/2015	7.86	153.0	106.0	<1.00	<2.00	<2.00	NaN	NaN	0.25	60.9	2.0	C
Columbia at Mica Outflow	2	04/22/2015	8.01	154.0	111.0	1.3	<2.00	6.4	NaN	NaN	0.16	63.7	3.0	C
Columbia at Mica Outflow	2	05/06/2015	7.92	154.0	99.8	<1.00	<2.00	<2.00	NaN	NaN	0.16	63.1	3.5	C
Columbia at Mica Outflow	2	05/25/2015	7.55	65.3	205.0	1.1	2.0	2.7	NaN	NaN	1.56	22.5	5.0	C
Columbia at Mica Outflow	2	06/08/2015	7.84	153	114.0	<1.00	<2.00	<2.00	NaN	NaN	0.24	63.3	4.5	LB
Columbia at Mica Outflow	2	07/06/2015	7.93	154	120.0	<1.00	<2.00	<2.00	NaN	NaN	0.36	64.1	5.0	C
Columbia at Mica Outflow	2	07/27/2015	7.91	149	92.9	<1.00	<2.00	2.5	NaN	NaN	0.75	60.9	7.0	C
Columbia at Mica Outflow	2	08/10/2015	7.99	156	122.0	2.3	<2.00	2.5	NaN	NaN	0.88	67.1	8.0	C
Columbia at Mica Outflow	2	09/08/2015	7.96	140	115.0	1.8	2.0	3.1	NaN	NaN	0.72	57.4	9.5	C
Columbia at Mica Outflow	2	10/05/2015	7.82	148	102.0	7.2	2.1	2.3	NaN	NaN	0.49	58.0	8.5	C

		Date	pH	Cond	NN	SRP	TDP	TP	TP Turb	TPc[1]	Turb	Alk [2]	T	Color [3]
Columbia at Mica Outflow	2	11/02/2015	8.03	144	97.6	2.7	<2.00	<2.00	NaN	NaN	0.81	59.6	8.5	C
Columbia at Mica Outflow	2	12/08/2015	7.94	149	107.0	<1.00	<2.00	2.1	NaN	NaN	0.29	62.6	4.0	C
Goldstream River	3	06/24/2008	7.73	75	1172.5	2.0	18.3	22.9	2.2	20.7	1.01	38	9.5	n/a
Goldstream River	3	08/05/2008	7.69	78	71.8	2.1	0.0	20.8	7.5	13.3	2.71	41	13.0	n/a
Goldstream River	3	05/11/2009	7.88	102	357.1	3.4	6.1	11.2	0.7	10.5	0.76	63	6.5	C
Goldstream River	3	05/27/2009	7.72	69	380.7	4	7.8	46.6	3.1	43.5	9.26	45	6.0	TB
Goldstream River	3	06/08/2009	7.77	73	247.7	2.3	4.4	9.1	0.6	8.5	1.86	46	11.0	TB
Goldstream River	3	06/29/2009	7.28	61	104.2	1.6	4.7	10.4	0.8	9.6	1.38	40	10.0	TB
Goldstream River	3	07/08/2009	7.31	56	81.2	0.9	3.8	13.1	1.6	11.5	4.11	37.5	8.0	C
Goldstream River	3	07/28/2009	7.64	65	57.2	2.2	9	177.3	116	61.3	189	40.5	14.0	TB
Goldstream River	3	08/11/2009	7.23	52	72.5	1	2.6	91.9	33	58.9	45.6	35	10.0	TB
Goldstream River	3	09/09/2009	7.58	79	100.8	1.2	2.5	13.3	3.7	9.6	2.55	51	8.0	C
Goldstream River	3	10/05/2009	7.76	100	193.4	1.4	4.9*	3.6	0.6	3	1.72	64.5	4.5	C
Goldstream River	3	11/03/2009	7.81	103	138.6	1.6	1.6	2.2	0.1	2.2	1.35	67	2.0	C
Goldstream River	3	05/04/2010	8.02	128	340.4	1.8	3.8	9.9	0.5	9.4	0.20	65	5.0	C
Goldstream River	3	05/31/2010	7.99	103	325.3	1.1	2.6	7.0	<0.1	6.9	0.44	51	7.0	C
Goldstream River	3	06/29/2010	7.61	66	90.8	2.3	8.3	65.3	6.7	58.6	14.10	33.5	7.5	TB
Goldstream River	3	07/05/2010	7.71	77	85.7	0.8	3.8	12.4	1.3	11.1	1.05	37	7.0	TB
Goldstream River	3	07/26/2010	7.82	76	60.0	1.0	4.3	95.6	24.9	70.7	44.75	36.9	11.5	TB
Goldstream River	3	08/09/2010	7.49	69	57.6	1.4	5.5	40.3	10.3	30.0	16.55	34.1	10.5	T
Goldstream River	3	09/07/2010	7.73	109	109.8	1.5	3.4	10.3	1.1	9.1	3.20	55.4	8.5	C
Goldstream River	3	10/05/2010	7.79	99	116.7	1.8	6.6	6.7	3.8	3.0	8.66	51	8.5	MGB
Goldstream River	3	11/01/2010	7.82	129	147.4	0.9	2.6	3.2	<0.1	3.1	0.46	68	4.0	C
Goldstream River	3	05/09/2011	7.99	112	220.3	1.8	5.2	9.5	<0.1	9.4	2.15	76	6.0	TGB
Goldstream River	3	05/30/2011	7.87	73	390.3	1.6	4.1	32.3	2.4	29.8	8.20	51	6.0	TB
Goldstream River	3	06/06/2011	7.80	59	295.2	1.5	3.8	151.0	13.7	137.3	30.0	40	7.0	TB
Goldstream River	3	06/28/2011	7.80	54	142.1	1.2	4.4	146.9	**	NaN	4.50	38.5	9.5	TB
Goldstream River	3	07/26/2011	7.73	52	37.2	1.2	4.9	14.0	1.9	12.2	8.15	37.5	10.5	TLB
Goldstream River	3	08/17/2011	7.66	96	96.2	1.4	2.9	6.3	0.9	5.5	1.60	47	9.5	C
Goldstream River	3	09/07/2011	7.88	110	118.7	1.1	3.5	17.6	**	NaN	7.10	55.5	9.5	TB
Goldstream River	3	10/19/2011	7.75	128	170.9	1.6	2.3	4.0	<0.1	3.9	1.20	64	7.0	C
Goldstream River	3	05/14/2012	7.57	111	382.1	3.3	6.8	34.4	2.2	32.3	2.80	55.4	6.5	M
Goldstream River	3	05/28/2012	7.80	90	361.5	4.5	4.7	73.9	4.9	69.1	6.25	47	6.0	TB
Goldstream River	3	06/05/2012	7.65	87	267.3	4.2	4.8	40.1	4.3	35.8	5.80	46.5	6.0	TB
Goldstream River	3	06/26/2012	7.85	77	130.4	2.6	3.8	73.3	14.1	59.2	45.00	42.1	6.0	TB
Goldstream River	3	07/09/2012	7.50	65	69.4	1.7	4.3	60.6	7.9	52.6	27.50	37	8.0	TB
Goldstream River	3	07/30/2012	7.65	67	65.4	1.4	3.4	31.3	5.9	25.4	4.04	37.2	10.0	TLB
Goldstream River	3	08/27/2012	7.94	87	93.3	2.4	3.1	13.4	5.5	7.9	1.45	50	10.0	C
Goldstream River	3	09/24/2012	7.88	89	84.4	2.2	4.9	11.4	4.7	6.7	8.33	48	9.0	M
Goldstream River	3	10/23/2012	7.98	110	149.3	1.6	6.2	7.4	<0.1	7.3	0.63	65	2.0	C
Goldstream River	3	11/19/2012	7.82	123	181.7	1.4	2.8	4.6	<0.1	4.5	0.47	69.6	2.0	C
Goldstream River	3	04/15/2013	8.05	177	240	<1.00	2.6	3.7	NaN	NaN	1.07	80.8	4.0	GC
Goldstream River	3	05/08/2013	7.78	89.7	564	1.7	3.3	78.7	NaN	NaN	35.3	37.5	4.5	B
Goldstream River	3	05/27/2013	7.81	112	309	<1.00	3.0	8.5	NaN	NaN	1.3	50.2	7.0	GC
Goldstream River	3	06/03/2013	7.81	105	247	1.5	2.8	3.6	NaN	NaN	1.85	46.7	7.0	GC

		Date	pH	Cond	NN	SRP	TDP	TP	TP Turb	TPc[1]	Turb	Alk [2]	T	Color [3]
Goldstream River	3	06/25/2013	7.58	81.5	86.7	1.7	<2.00	5.9	NaN	NaN	6.4	33.9	7.5	BG
Goldstream River	3	07/08/2013	7.76	88.2	91.2	2.3	<2.00	10.9	NaN	NaN	4.57	37.8	10.0	MG
Goldstream River	3	08/06/2013	7.85	95.7	66.9	1.7	12.5	78.7	NaN	NaN	49.5	43.7	12.0	MB
Goldstream River	3	09/11/2013	7.76	94.9	70.5	<1.00	9.4	16.0	NaN	NaN	0.24	39.8	10.0	B
Goldstream River	3	09/30/2013	7.95	119	139	2.2	2.1	2.7	NaN	NaN	3.4	51.2	6.0	GC
Goldstream River	3	11/05/2013	7.95	158	169	<1.00	<2.00	<2.00	NaN	NaN	0.61	68.7	1.0	C
Goldstream River	3	05/26/2014	7.82	101	411.0	4.4	2.5	36.0	NaN	NaN	13.40	42.1	4.0	B
Goldstream River	3	06/09/2014	7.87	97	255.0	1.1	2.1	2.2	NaN	NaN	4.85	41.3	6.0	B
Goldstream River	3	07/08/2014	7.74	76	76.9	3.4	<2.00	14.9	NaN	NaN	7.48	33.3	8.0	MG
Goldstream River	3	08/06/2014	7.88	88	79.8	1.2	3.8	23.4	NaN	NaN	13.60	40.4	12.0	MG
Goldstream River	3	09/02/2014	7.75	108	99.7	2.6	<2.00	19.9	NaN	NaN	5.20	41.6	8.0	MG
Goldstream River	3	10/07/2014	7.79	107	112.0	5.9	2.0	6.7	NaN	NaN	6.22	41.6	8.0	MG
Goldstream River	3	03/25/2015	8.03	168	257.0	<1.00	<2.00	<2.00	NaN	NaN	0.36	75.2	3.0	VC
Goldstream River	3	04/07/2015	7.94	169	317.0	3.1	6.3	45.1	NaN	NaN	0.33	73.7	2.5	C
Goldstream River	3	04/22/2015	7.99	146	383.0	1.3	2.5*	2.2	NaN	NaN	0.66	65.0	6.0	GC
Goldstream River	3	05/06/2015	7.91	132	413.0	<1.00	<2.00	2.8	NaN	NaN	0.91	56.8	4.5	MG
Goldstream River	3	05/25/2015	7.73	87.8	243.0	<1.00	3.1	4.8	NaN	NaN	9.33	36.5	7.0	B
Goldstream River	3	06/08/2015	7.56	76.0	90.2	1.3	2.3	9.6	NaN	NaN	17.00	32.7	7.0	B
Goldstream River	3	07/06/2015	7.76	89.0	81.0	<1.00	<2.00	4.5	NaN	NaN	6.58	36.3	11.0	MG
Goldstream River	3	07/27/2015	7.76	95.8	63.8	<1.00	<2.00	3.9	NaN	NaN	4.44	38.2	10.0	MG
Goldstream River	3	08/10/2015	7.75	79.8	69.1	1.8	<2.00	9.8	NaN	NaN	23.70	34.1	12.0	GB
Goldstream River	3	09/08/2015	7.81	134	152.0	2.9	2.1	3.3	NaN	NaN	0.96	52.5	Not Taken	C
Goldstream River	3	10/05/2015	8.05	150	167.0	<1.00	2.1	4.3	NaN	NaN	2.89	62.8	5.5	GC
Goldstream River	3	11/02/2015	8.05	154	183.0	4.9	<2.00	2.0	NaN	NaN	2.37	66.6	3.5	C
Goldstream River	3	12/08/2015	8.10	170	215.0	3.6	2.0	3.7	NaN	NaN	1.77	76.8	-1.0	C 1/2F
Columbia above Jordan [4]	4	06/24/2008	7.94	118	144.3	2.7	6.7	8.2	1.0	7.2	0.16	50	10.0	n/a
Columbia above Jordan	4	05/12/2009	7.83	108	125.7	2.4	5.6*	3.2	0.1	3.2	0.32	64	4.0	C
Columbia above Jordan	4	05/28/2009	7.89	103	117.3	2.6	4.5	5.6	0.1	5.6	0.59	63	7.0	C
Columbia above Jordan	4	06/09/2009	7.87	105	121.2	3	6.7*	4.2	0.1	4.2	0.37	64	7.0	C
Columbia above Jordan	4	06/30/2009	7.42	92	134.9	2	5.3*	4.9	0.1	4.9	0.43	56	10.0	C
Columbia above Jordan	4	07/07/2009	7.57	94	134.9	1.6	4.8	5.2	0.1	5.2	0.63	58.4	7.0	C
Columbia above Jordan	4	07/27/2009	7.49	75	126.7	3.1	3.3	4.7	0.1	4.7	0.63	49	9.5	C
Columbia above Jordan	4	08/10/2009	7.28	71	140.5	1.1	3.7	4.3	0.1	4.3	0.36	45.4	8.0	C
Columbia above Jordan	4	09/08/2009	7.44	83	122.8	1.4	4.2*	3.8	0.7	3.1	0.58	52.6	9.0	C
Columbia above Jordan	4	10/06/2009	7.56	76	138.9	1.1	4.4*	4.3	0.8	3.5	1.09	50	10.5	C
Columbia above Jordan	4	11/02/2009	7.54	89	107.9	1.6	1.5	2.7	0.1	2.7	0.83	55.2	5.0	C
Columbia above Jordan	4	05/03/2010	7.98	137	100.5	1.6	3.1	3.5	<0.1	3.4	0.17	63.7	4.5	C
Columbia above Jordan	4	05/31/2010	8.04	140	116.2	1.1	5.6*	3.4	<0.1	3.3	0.25	66.6	8.0	C
Columbia above Jordan	4	06/28/2010	7.84	121	128.7	1.1	4.4*	3.7	<0.1	3.6	0.22	59.5	7.0	C
Columbia above Jordan	4	07/06/2010	7.86	116	132.6	1.0	3.9*	3.8	<0.1	3.7	0.39	56	8.5	C
Columbia above Jordan	4	07/27/2010	7.82	97	134.2	2.1	3.6	4.6	0.8	3.9	0.62	46.7	10.0	C
Columbia above Jordan	4	08/09/2010	7.54	89	133.3	1.5	3.0	3.9	<0.1	3.8	0.37	44.2	10.0	C
Columbia above Jordan	4	09/08/2010	7.40	72	136.2	2.1	3.2	3.2	<0.1	3.1	1.49	34.7	10.5	C
Columbia above Jordan	4	10/07/2010	7.58	85	104.5	1.3	5.7*	5.2	<0.1	5.1	0.49	42	11.0	C
Columbia above Jordan	4	11/02/2010	7.52	100	111.2	1.0	2.8	6.2	4.0	2.2	1.40	51	8.0	C

		Date	pH	Cond	NN	SRP	TDP	TP	TP Turb	TPc[1]	Turb	Alk [2]	T	Color [3]
Columbia above Jordan	4	05/09/2011	7.88	102	100.7	1.3	5.4*	4.6	<0.1	4.5	0.48	64	4.0	C
Columbia above Jordan	4	05/31/2011	7.96	94	106.4	0.9	3.2	3.9	<0.1	3.8	0.50	61.7	5.5	C
Columbia above Jordan	4	06/06/2011	7.95	93	102.8	1.0	4.0*	3.7	<0.1	3.6	0.90	60	6.5	C
Columbia above Jordan	4	06/28/2011	7.88	81	165.1	1.4	3.8	5.2	<0.1	5.1	1.10	55.5	8.5	C
Columbia above Jordan	4	07/25/2011	7.73	59	154.1	1.6	2.8	3.7	0.7	2.9	1.60	41.9	9.5	C
Columbia above Jordan	4	08/17/2011	7.46	81	124.9	1.3	15.3*	2.2	0.3	1.9	0.95	38	8.0	C
Columbia above Jordan	4	09/07/2011	7.67	100	112.8	0.9	3.0	4.7	**	NaN	0.60	47	9.0	C
Columbia above Jordan	4	10/19/2011	7.64	111	107.0	1.1	2.8*	2.8	<0.1	2.7	0.45	51.5	9.0	C
Columbia above Jordan	4	05/14/2012	7.64	137	85.5	2.8	6.3	9.0	1.0	8.0	0.45	64.55	6.5	C
Columbia above Jordan	4	05/28/2012	7.96	127	107.6	4.0	5.5	6.0	1.3	4.7	0.13	62.5	6.0	C
Columbia above Jordan	4	06/05/2012	7.87	124	119.3	4.0	4.8	6.9	0.7	6.2	0.00	63.6	6.0	C
Columbia above Jordan	4	06/26/2012	7.94	104	148.1	2.0	4.0	3.8	0.7	3.1	0.00	52.6	8.0	C
Columbia above Jordan	4	07/09/2012	7.71	93	151.8	2.1	6.5	7.1	0.8	6.3	0.05	48.2	8.0	C
Columbia above Jordan	4	07/30/2012	7.58	68	111.4	1.8	3.4	6.4	2.0	4.4	1.18	35.8	10.0	C
Columbia above Jordan	4	08/28/2012	7.93	95	113.6	2.8	4.9	4.9	1.3	3.6	0.15	52.6	11.0	C
Columbia above Jordan	4	09/24/2012	7.92	104	109.4	2.8	3.8	4.1	<0.1	4.0	0.30	56.46	11.0	C
Columbia above Jordan	4	10/23/2012	7.95	109	102.8	1.1	4.8	5.5	<0.1	5.4	0.32	61	8.5	C
Columbia above Jordan	4	11/19/2012	7.79	111	124.0	1.3	1.5	4.0	<0.1	3.9	0.28	60.4	7.0	C
Columbia above Jordan	4	04/15/2013	7.98	156	111	<1.00	<2.00	3.2	NaN	NaN	0.53	67.7	4.0	C
Columbia above Jordan	4	05/08/2013	7.88	149	110	<1.00	<2.00	2.1	NaN	NaN	0.18	64.1	6.0	C
Columbia above Jordan	4	05/27/2013	7.97	149	111	<1.00	<2.00	<2.00	NaN	NaN	0.21	64.4	5.0	C
Columbia above Jordan	4	06/03/2013	7.9	139	133	<1.00	<2.00	2.9	NaN	NaN	0.024	59.3	7.0	C
Columbia above Jordan	4	06/25/2013	7.74	121	181	<1.00	<2.00	<2.00	NaN	NaN	0.79	48.7	7.5	C
Columbia above Jordan	4	07/08/2013	7.82	112	176	<1.00	<2.00	<2.00	NaN	NaN	0.37	48.2	8.0	C
Columbia above Jordan	4	08/06/2013	7.58	83.9	128	1.4	15.3	19.9	NaN	NaN	0.62	35.2	10.0	C
Columbia above Jordan	4	09/11/2013	7.66	106	105	1.6	2.0	2.3	NaN	NaN	0.11	42.6	11.5	C
Columbia above Jordan	4	09/30/2013	7.95	124	118	1.4	2.3	5.5	NaN	NaN	1.19	51.6	9.0	C
Columbia above Jordan	4	11/05/2013	7.83	123	116	<1.00	<2.00	<2.00	NaN	NaN	0.3	50.3	8.0	C
Columbia above Jordan	4	05/27/2014	7.78	142	117.0	2.7	<2.00	<2.00	NaN	NaN	0.27	56.2	4.0	C
Columbia above Jordan	4	06/09/2014	8.06	140	128.0	<1.00	<2.00	2.7	NaN	NaN	0.28	59.3	5.0	C
Columbia above Jordan	4	07/08/2014	7.86	118	170.0	<1.00	<2.00	2.2	NaN	NaN	0.45	50.0	8.0	C
Columbia above Jordan	4	08/05/2014	7.78	89	144.0	1.3	4.1	6.1	NaN	NaN	0.89	35.7	9.0	C
Columbia above Jordan	4	09/02/2014	7.83	111	122.0	1.0	<2.00	<2.00	NaN	NaN	0.61	45.6	8.0	C
Columbia above Jordan	4	10/06/2014	7.84	127	123.0	1.2	<2.00	<2.00	NaN	NaN	0.82	52.0	8.0	C
Columbia above Jordan	4	03/25/2015	7.96	145	123.0	<1.00	<2.00	<2.00	NaN	NaN	0.19	61.5	2.0	C
Columbia above Jordan	4	04/08/2015	7.85	146	115.0	1.9	29.3	56.0	NaN	NaN	0.18	60.3	2.0	C
Columbia above Jordan	4	04/22/2015	7.99	147	123.0	4.1	<2.00	<2.00	NaN	NaN	0.32	63.0	3.5	C
Columbia above Jordan	4	05/07/2015	7.93	144	121.0	<1.00	2.5*	2.4	NaN	NaN	0.18	58.7	4.5	C
Columbia above Jordan	4	05/26/2015	7.87	145	132.0	<1.00	2.3	7.9	NaN	NaN	0.33	60.7	6.0	C
Columbia above Jordan	4	06/08/2015	7.78	131	140.0	<1.00	<2.0	<2.00	NaN	NaN	0.53	54.4	7.0	C
Columbia above Jordan	4	07/06/2015	7.79	106	141.0	1.5	7.8*	<2.00	NaN	NaN	0.49	41.6	8.5	C
Columbia above Jordan	4	07/27/2015	7.83	122	72.2	<1.00	2.0	4.4	NaN	NaN	0.60	50.2	9.0	C
Columbia above Jordan	4	08/10/2015	7.80	130	114.0	<1.00	<2.00	2.2	NaN	NaN	0.64	55.1	10.0	C
Columbia above Jordan	4	09/08/2015	7.88	143	122.0	1.1	<2.00	2.7	NaN	NaN	0.63	55.0	10.0	C
Columbia above Jordan	4	10/05/2015	7.94	134	99.2	<1.00	<2.00	2.3	NaN	NaN	0.72	54.7	10.0	C

		Date	pH	Cond	NN	SRP	TDP	TP	TP Turb	TPc[1]	Turb	Alk [2]	T	Color [3]
Columbia above Jordan	4	11/02/2015	8.04	145	192.0	3.2	<2.00	2.4	NaN	NaN	2.45	60.2	8.0	C
Columbia above Jordan	4	12/08/2015	8.09	165	289.0	2.4	3.9*	3.3	NaN	NaN	0.63	72.8	6.0	C
Beaver River	6	05/06/2013	7.87	108	533	1.9	2.1	217.0	NaN	NaN	62.6	44.9	4.0	B
Beaver River	6	05/28/2013	7.82	100	239	1.7	2.3	8.1	NaN	NaN	3.33	39.5	5.0	C
Beaver River	6	06/04/2013	7.71	88.2	187	1.9	3.1	6.4	NaN	NaN	3.16	36.2	5.5	C
Beaver River	6	06/24/2013	7.55	81.7	83.2	2.6	<2.00	5.8	NaN	NaN	9.14	30.7	6.0	TG
Beaver River	6	07/09/2013	7.77	85.1	74.1	3.6	<2.00	9.7	NaN	NaN	8.03	34.1	6.0	C
Beaver River	6	08/07/2013	7.57	66.4	47.2	6.2	10.8	37.1	NaN	NaN	20.8	28	8.0	M
Beaver River	6	09/10/2013	7.5	71.4	49.7	5.5	11.8	17.0	NaN	NaN	0.23	28.5	7.0	M
Beaver River	6	10/01/2013	7.93	125	110	2.1	<2.00	<2.00	NaN	NaN	2.33	50.9	5.0	C
Beaver River	6	11/04/2013	7.93	159	133	<1.00	<2.00	2.5	NaN	NaN	0.74	64	1.0	C
Beaver River	6	05/27/2014	7.61	83	327.0	3.3	<2.00	15.2	NaN	NaN	10.70	31.6	3.5	GB
Beaver River	6	06/10/2014	7.74	77	173.0	<1.00	<2.00	2.2	NaN	NaN	6.53	29.7	3.0	MG
Beaver River	6	07/09/2014	7.65	70	64.1	5.0	<2.00	17.4	NaN	NaN	6.25	28.7	6.0	MG
Beaver River	6	08/05/2014	7.71	73	53.9	<1.00	4.0	9.7	NaN	NaN	5.14	28.8	7.0	MG
Beaver River	6	09/03/2014	7.74	86	65.5	5.2	<2.00	6.9	NaN	NaN	8.12	34.2	6.0	MG
Beaver River	6	10/06/2014	7.73	101	82.2	2.7	<2.00	3.8	NaN	NaN	2.02	38.7	6.0	C
Beaver River	6	04/23/2015	7.84	120	420.0	<1.00	4.9*	3.8	NaN	NaN	1.39	49.1	2.5	B
Beaver River	6	05/07/2015	7.79	119	381.0	<1.00	<2.00	2.5	NaN	NaN	0.77	46.7	4.0	C
Beaver River	6	05/26/2015	7.65	77.6	189.0	<1.00	2.6	4.8	NaN	NaN	10.20	30.0	4.0	B
Beaver River	6	06/09/2015	7.51	69.7	81.0	<1.00	2.5	16.6	NaN	NaN	61.60	27.4	5.0	B
Beaver River	6	07/07/2015	7.68	75.8	59.4	<1.00	<2.00	7.4	NaN	NaN	11.60	31.6	8.0	MG
Beaver River	6	07/28/2015	7.54	84.5	43.3	<1.00	<2.00	4.2	NaN	NaN	5.63	31.1	7.0	M
Beaver River	6	08/11/2015	7.65	70.7	50.0	1.5	<2.00	10.2	NaN	NaN	12.90	30.1	8.0	M
Beaver River	6	09/08/2015	7.89	120	108.0	1.4	2.8	4.0	NaN	NaN	1.84	45.6	7.0	C
Beaver River	6	10/06/2015	7.90	137	121.0	2.1	2.4	2.5	NaN	NaN	1.83	51.9	4.0	C
Beaver River	6	11/03/2015	8.01	150	144.0	<1.00	2.7*	<2.00	NaN	NaN	1.74	58.7	2.0	C
Beaver River	6	12/07/2015	8.04	159	166.0	1.5	2.2	2.7	NaN	NaN	1.07	65.8	0.0	C

1 TP=TP-Tpturb Total phosphorus corrected for turbidity
2 Corrected Alkalinity 2008 - 2012
3 (C)lear, (T)urbid, (M)ilky, (G)reen, (B)rown, (S)lightly, (L)ight, (V)ery, (F)rozen
4 Columbia above Jordan is located just below Revelstoke Dam
* TDP > TP, values swapped in figures and analysis
** TPTurb not measured

Appendix 3.2
Station: Beaver River near East Park Gate (BC08NB0002)
Raw data from Environment Canada

Date Time	ALK-T	Ca	Cl	K	Mg	Na	NH3	NO2	NO3	pH	OP	TP	SO4	Cond	T	Turb	TN	TND	TDP
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	pH	mg/L	mg/L	mg/L	uS/c	deg C	NTU	mg/L	mg/L	mg/L
11/12/2013 17:50	80.0	25.4	0.8	0.4	8.4	1.7	NaN	0.005	0.151	8.01	NaN	0.001	18.0	197	0	NaN	NaN	0.14	NaN
1/20/2014 19:35	88.6	28.2	0.8	0.4	9.1	1.9	NaN	NaN	NaN	7.93	NaN	0.005	18.4	208	-0.7	NaN	NaN	0.15	NaN
2/18/2014 18:40	86.7	25.8	0.9	0.5	9.0	2.0	NaN	0.005	0.180	7.93	NaN	0.002	19.2	207	-0.2	NaN	NaN	0.16	NaN
3/24/2014 19:05	91.5	29.3	1	0.4	9.3	2.1	NaN	0.021	NaN	8.08	NaN	0.004	18.2	216	0	1.44	NaN	0.13	NaN
4/22/2014 19:06	78.7	24.7	3.4	0.5	7.1	3.1	NaN	0.005	0.237	7.95	NaN	0.006	15.2	191	3.9	1.29	NaN	0.24	NaN
5/26/2014 16:45	44.1	14.7	0.9	0.3	3.9	1	NaN	NaN	NaN	7.93	NaN	0.032	8.4	103	7.8	NaN	NaN	0.33	NaN
6/17/2014 8:00	44.6	15.3	0.3	0.2	4.7	0.8	NaN	NaN	NaN	7.98	NaN	0.009	8.4	104	7.8	NaN	NaN	0.13	NaN
9/30/2014 17:40	33.8	12.8	0.2	0.3	2.8	0.5	NaN	NaN	NaN	7.72	NaN	0.002	8.5	84	6	NaN	NaN	0.07	NaN
10/21/2014 19:00	46.1	16.8	0.4	0.4	4.1	0.7	NaN	0.005	0.089	7.92	NaN	0.007	11.2	114	7.6	NaN	0.11	0.1	NaN
11/17/2014 18:00	68.5	21.7	0.9	0.4	6.8	1.5	NaN	NaN	NaN	7.81	NaN	0.002	14.7	619*	-0.7	NaN	0.22	0.21	NaN
12/15/2014 19:15	75.7	20.6	1.01	0.4	7	1.6	NaN	NaN	NaN	7.89	NaN	0.002	16.2	175	-0.3	NaN	0.19	0.19	NaN
1/26/2015 17:30	77.6	23.9	0.65	0.4	8.2	1.7	NaN	NaN	NaN	7.96	NaN	0.002	11.1	190	0.5	NaN	0.18	0.17	NaN
2/24/2015 18:22	83.9	24.9	1.38	0.4	7.8	2.2	NaN	NaN	NaN	7.95	NaN	0.001	15.2	196	0.9	NaN	0.18	0.17	NaN
3/24/2015 18:50	75.6	22.1	2.1	0.4	7.3	2.5	NaN	0.005	0.209	8.02	NaN	0.002	13.1	174	2.5	NaN	0.23	0.22	NaN
4/21/2015 17:51	68.5	21.5	1.27	0.4	6.6	1.9	NaN	NaN	NaN	7.98	NaN	0.004	10.7	166	5.4	3.06	0.32	0.31	NaN
7/20/2015 16:45	27.6	10.6	0.08	0.3	2.1	0.4	NaN	0.005	0.033	7.69	NaN	0.045	4.3	62	7.9	NaN	0.07	0.05	NaN
11/24/2015 20:00	78	21.6	0.68	0.3	7.9	1.5	NaN	NaN	NaN	7.89	NaN	NaN	17.9	184	0.3	NaN	0.16	0.16	NaN
1/18/2016 18:50	86.6	25.9	0.86	0.4	NaN	NaN	NaN	NaN	NaN	NaN	NaN	0.003	NaN	204	NaN	NaN	NaN	0.16	NaN

*Outlier, not included in figures.

Appendix 3

CTD Surveys
Kinbasket and Revelstoke Reservoirs, 2015

Roger Pieters and Greg Lawrence
University of British Columbia

CTD Surveys
Kinbasket and Revelstoke Reservoirs, 2014 and 2015

Roger Pieters[1,2] and Greg Lawrence[2]

[1] Earth and Ocean Sciences, University of British Columbia, Vancouver, B.C. V6T 1Z4
[2] Civil Engineering, University of British Columbia, Vancouver, B.C. V6T 1Z4

Revelstoke Reservoir, from Downie Boat launch, 20 May 2014

Prepared for

Karen Bray
British Columbia Hydro and Power Authority
1200 Powerhouse Road
Revelstoke B.C. V0E 2S0

January 18, 2017

Contents

List of Figures

1. Introduction

We report on CTD (conductivity-temperature-depth) profiles collected from Kinbasket and Revelstoke Reservoirs in 2014 and 2015. These data were collected as part of year seven and eight of the B.C. Hydro project "CLBMON-3 Kinbasket and Revelstoke Ecological Productivity Monitoring".*

2. Methods

Sampling stations

Sampling Kinbasket and Revelstoke Reservoirs is challenging because of their size. The Columbia and Canoe Reaches of Kinbasket Reservoir stretch over 180 km (Figure A1). Revelstoke Reservoir is not quite as long, with 130 km between Mica and Revelstoke Dams. Kinbasket is particularly difficult to sample because of limited road access, the frequency and severity of wind storms, the presence of woody debris, and the absence of sheltered locations along much of the reservoir.

The location of the sampling stations is shown in Figure A1. Stations are numbered either from the dam or from the mouth of an arm. In Kinbasket there are five main stations: Forebay (K1fb), Middle (K2mi), Columbia Reach (K3co), Canoe Arm (Kca1), and Wood Arm (Kwo1). In Revelstoke there are three main stations: Forebay (R1fb), Middle (R2mi) and Upper (R3up). Station locations are given in Appendix 1.

Sampling was conducted in both reservoirs monthly from May to October 2014, and April to October 2015. A list of the profiles collected in 2014 and 2015 is given in Appendix 2, and a summary is given in Tables 2.1 and 2.2.

The profiler was tested 10 km from the Revelstoke forebay on 9 April 2015. In 2014 and 2015, intensive CTD surveys were not undertaken in Kinbasket Reservoir, but were undertaken in Revelstoke Reservoir on 11 June 2014 and 14-15 October 2014, 21 April 2015, 12 August 2015, and 29 September 2015. Additional casts were collected during measurement of primary production, and these data are shown in Appendix 4.

* Previous data include profiles from Revelstoke Reservoir and the Mica Forebay (Watson 1984; Fleming and Smith 1988). Monthly profiles at four stations in Kinbasket Reservoir (2003, 2004 and 2005) and three stations in Revelstoke Reservoir (2003) were collected with an YSI multiparameter probe (K. Bray, personal communication).

Profiler

Profiles were collected using a Sea-Bird Electronics SBE 19plus V2 profiler with the following additional sensors:

- Turner SCUFA II fluorometer and optical back scatter (OBS) sensor,
- Biospherical QSP-2300L (4 pi) photosynthetically active radiation (PAR) sensor,
- Sea-Bird SBE 43 dissolved oxygen sensor, and
- Wetlabs CStar transmissometer (red with 25 cm path).

Secchi depths were collected with a 20 cm diameter black and white disk, lowered from the side of the boat away from the sun. The Secchi depth is given as the average of the depths at which the disk disappeared going down and reappeared going up. Multiplying the Secchi depth by 2.6 provides an estimate of the 1% light level (Figure A4).

Pump problems From 2009 to 2011 the pump on the profiler did not turn on due to a problem with the setting of the parameter for the minimum conductivity frequency; for more detail see Appendix 3. The pump affects the temperature, conductivity, and dissolved oxygen readings; even with the pump off, most of the temperature and conductivity data collected was satisfactory as descent forced water through the plumbing.

From 2012 onward, the minimum conductivity frequency was correctly set to zero. In 2012 casts were collected to evaluate the effect of having the pump turned off. For casts with the pump on and off, the temperature and conductivity data were very similar. However, having the pump off did affect the dissolved oxygen readings, and as a result the oxygen data for 2009-2011, other than confirming generally oxygenated conditions, were not accurate. The data for light transmission and fluorescence (Chl a) are independent of the pump. For further detail see Pieters and Lawrence (2014a).

Early descent After the Seabird is turned on:

- it is hung in the air for 60 sec,
- it is lowered into the water to soak for 90 sec, and
- at 150 sec from the start, the Seabird is lowered, beginning the descent.

The pump comes on half way through the soak at 105 sec (420 scans). However, in 2013, the descent had erroneously begun at 90 sec from the start, earlier than in previous years. As a result, the pump did not turn on until the Seabird was at a depth of 4-6 m. The data before the pump turned on was removed from the plots, and as a result most plots begin at 4-6 m depth. As observed in past years, the top 5 m is often relatively uniform, not unexpected given wind mixing in these large reservoirs. In 2014 and 2015, this problem did not occur as all casts were in the water by scan 420, and none of the casts began descent before scan 420.

Problem transmissometer data The transmissometer assesses the clarity of the water, returning a higher voltage when light transmission is higher (clearer water), and returning a lower voltage when less light is transmitted through the water (the water is more turbid). Other than lenses of turbidity, the readings in Kinbasket and Revelstoke Reservoir are generally fairly high (Figure F1.1e).

In 2015, beginning with cast 38, the transmissometer data was observed to intermittently drop suddenly to very low readings (low voltage), or to have a low reading for the entire profile. For example, of the profiles in Figure D2.5d, three of the profiles show low readings throughout (0%, below the y axis, casts 51, 47 and 48); in two profiles the readings jumped from 0% to normal as the profiler descended (casts 49 and 53); and in one profile, the data appears normal throughout (cast 50). This intermittent change is likely the result of a connector problem in the transmissometer, or a cable problem between the transmissometer and the profiler. Problematic data were observed in about 40% of the casts. Line and contour plots of this data should be disregarded.

Table 2.1a Kinbasket surveys, 2014

Date	FB K1	K1.5	MI K2	CO K3	CA Kcal	WO Kwol
3 June	✓		✓	✓	✓	✓
16-17 June	✓		✓	✓	✓	✓
25 June		✓*				
14-15 July	✓		✓	✓	✓	✓
23 July		(1)				
11-12 August	✓		✓	✓	✓	✓
20 August		✓*				
15-16 September	✓		✓	✓	✓	✓
24 September		✓*				
20 October					✓	✓

* Collected during measurement of primary production (See Appendix 3)
(1) PP measured but no SBE cast collected

Table 2.1b Kinbasket surveys, 2015

Date	FB K1	K1.5	MI K2	CO K3	CA Kcal	WO Kwol
13 April	✓				✓	✓
11-12 May	✓		✓	✓	✓	✓
15-16 June	✓		✓	✓	✓	✓
24 June		✓*				
13-14 June	✓			✓	✓✓	✓
23 July		✓*				
23-24 August	✓		✓	✓	✓	✓
26 August		✓*				
21-22 September	✓	✓*	✓	✓	✓	✓
13 October	✓					

* Collected during measurement of primary production (See Appendix 3)

Table 2.2a Revelstoke surveys, 2014

Date	FB	MI	UP	Downie Rd0	Downie Rd1
21 May	✓	✓	✓	✓	✓
11 June	✓+4	✓+3	✓	✓	✓
23-24 June	✓*+1	✓	✓	✓	✓
26 June		✓*			
21 July		✓			
24 July		(1)			
18-19 August	✓*+1	✓	✓	✓	✓
21 August		✓*			
22-23 September	✓*+1	✓	✓	✓	✓
25 September		✓*			
14-15 October	✓+4	✓+4	✓	✓	✓

* Collected during measurement of primary production (See Appendix 3)
(1) PP measured but no SBE cast collected

Table 2.2b Revelstoke surveys, 2015

Date	FB	MI	UP	Downie Rd0	Downie Rd1
9 April	R1.28				
21 April	✓+4	✓+3	✓	✓	✓
27 April	✓+1				
19-20 May	✓	✓	✓	✓	✓
22-25 June	✓*	✓✓*	✓	✓	✓
20-23 July	✓*	✓✓*	✓	✓	✓
12 August	✓+4	✓+3	✓	✓	✓
24-27 August	✓✓*	✓*	✓	✓	✓
14-15 September	✓	✓	✓	✓	✓
23-24 September	✓*	✓*			
29 September	✓+4	✓+3	✓	✓	✓
19-20 October	✓	✓	✓	✓	✓

* Collected during measurement of primary production (See Appendix 3)

3. Results

We first look at the water levels and flows during 2014 and 2015, shown in Figure A2.1 and A2.2, respectively. In 2014, the first survey in Kinbasket Reservoir was undertaken in early June, after the reservoir had begun to fill (Figure 2.1a). The last survey was in early October, when the water level was high; while the water level rose very high in 2014 it remained slightly below normal full pool in fall (Figure A2.1a inset). In 2015, the surveys began earlier and included casts around minimum pool (Figure A2.2a). The center of the outlet from Kinbasket Reservoir is located 64.6 m below normal full pool.

In Revelstoke Reservoir there is normally little variation in water level (< 1.3 m), but in winter 2014 the water level experienced three brief drawdowns below normal minimum (Figure A2.1b). The mid-depth of the outlet at Revelstoke Dam is 28 m below full pool.

Next, consider the conductivity of the tributary inflows. For example, the main inflow to Kinbasket Reservoir, the Columbia River at Donald, was sampled under the Canada - British Columbia Water Quality Monitoring Agreement every two weeks from 1984-1995 including during ice-cover in winter. Water temperature, conductivity and flow for this period are shown in Figure A3. Water temperature varied from 12 to 19 ºC in summer, and cooled to 0-5 ºC in winter.

The conductivity of the Columbia River at Donald varied significantly over the year. In winter the flow was more saline with a conductivity of 300-350 µS/cm. At the start of freshet in spring, the conductivity decreased rapidly to 150-200 µS/cm, about half of the winter value. During freshet, the contribution of more saline groundwater to the river is diluted by fresh snowmelt and rain. In the fall the conductivity gradually increased as the freshet flow declined. A similar pattern was seen for the Beaver, Goldstream and Illecillewaet rivers (Pieters et al. 2017b). This seasonal change in the conductivity of the inflow will assist in identifying water masses as discussed below.

3.1 Kinbasket Reservoir

3-4 June 2014 Line plots for the surveys of Kinbasket Reservoir are shown in Figures B. In June 2014, seasonal stratification was well underway, with surface temperature ranging from 10 to 13 ºC (Figure B1.1b). During this time, the outlet from Kinbasket Reservoir was 43 m below the surface, as marked with the dotted lines in Figure B1.1.

The conductivity varied from ~150 µS/cm near the surface to ~200 µS/cm at depth throughout most of the reservoir (Figure B1.1c). The exception was the Columbia reach, K3co, which had a higher conductivity of 180-240 µS/cm (black, Figure B1.1c). The station at K3co is located at the former Kinbasket Lake on the Columbia Reach, and the conductivity of the water below 80 m remained distinctly different (Figures B1.1c to B1.5c) and relatively unchanged (Figure B1.9c) throughout the summer. In Canoe Reach, slightly reduced conductivity around 20 m suggests low-conductivity inflow (green, Figure B1.1c).

The reservoir was generally clear (high light transmission) with somewhat reduced transmission in the top 30 m especially in Wood Arm (cyan, Figure B1.1d). Dissolved oxygen was high (>9 mg/L) throughout the reservoir (Figure B1.1e). The nominal concentration of chlorophyll showed peaks of just over 1 µg/L near the depth of the 1% light level (Figure B1.1g). The 1% light level determined from PAR is marked with dashed lines; the 1% light level varied from 5 to 25 m.

16-17 June 2014 In June, surface temperature varied from 12 to 14 ºC (Figure B1.2b), showing the beginnings of a broad thermocline extending from the surface to 50 m depth. The most notable feature in the conductivity plot, is the decline of the conductivity in the top 60 m in the Columbia Reach (black, Figure B1.2c). In June, there were also layers of high turbidity (low light transmission) in Wood Arm (blue), and the Columbia Reach (black, Figure B1.2d).

14-15 July 2014 In July, surface temperature varied from 17 to 21 ºC (Figure B1.3b). As in June, there was a broad thermocline, now extending from the surface to 60 m depth. The stratification is slightly reduced in the top 10 m in one the casts, suggesting some surface mixing. In the conductivity plot, the most notable feature is again the decline in the conductivity in the top 60 m, at K3co (black, compare Figure B1.2c and Figure B1.3c).

The turbidity in the top 60 m was generally similar to that in mid-June, but showed layers of very high turbidity (low light transmission) in Wood Arm (blue), Canoe Reach (green) and the Columbia Reach (black, Figure B1.3d). Oxygen remained high (Figure B1.3e,f). In July, the chlorophyll layer around 10 m was similar to that observed in mid-June (Figure B1.3g).

11-12 August 2014 The temperature at the surface warmed to ~20 ºC at all stations, and the broad thermocline extended to about 60 m (Figure B1.4b). The overall conductivity of the surface layer continued to decline in the Columbia Reach (Figure B1.4c). All locations showed layers of turbidity between 20 and 50 m, with the highest turbidity in Wood Arm (cyan, Figure B1.4d).

The solubility of oxygen is sensitive to temperature, decreasing as temperature increases. As a result, the concentration of oxygen in the warmer surface layer was slightly lower in August than earlier in the year (e.g. Figure B1.4e). To remove the effect of temperature, dissolved oxygen is also plotted as percent saturation in Figure B1.4f. The saturation of dissolved oxygen was near saturation at the surface and decreased to ~80% at depth, indicating that the water was well oxygenated as would be expected for an oligotrophic system.

Fall 2014 By mid-September the surface had cooled to 15 ºC (Figure 1.5b), and by mid-October the surface had cooled to 12 ºC, and a distinct surface mixed layer was observed to 30 m depth (in the two profiles available, Figure B1.6b). Turbid layers remained below this surface mixed layer (Figures B1.5d and B1.6d).

April to October 2015 Line plots of CTD casts collected in 2015 are shown in Figures B2.1-B2.12. Note the intermittent problem with the transmissometer data described in the methods.

Seasonal changes Seasonal changes at the Forebay (K1fb), Middle (K2mi), Columbia (K3co), Canoe (Kca1) and Wood (Kwo1) stations, are shown respectively in Figures B1.7 to B1.11 for 2014, and B2.8 to B2.12 for 2015. To account for the increase in the water level, the casts are plotted relative to full pool, 754.4 mASL. In each case, changes in temperature and conductivity below 60 m are small. Oxygen below 60 m declined only slightly (≤1 mg/L) over the summer.

Contour plots The profiles along the length of Kinbasket Reservoir are shown as contour plots in Figures C1.1-C1.5 in 2014 and C2.1-C2.5 in 2015. Each contour shows Canoe Reach (Kca1), the main pool (K2mi) and Columbia Arm (K3co). Contour plots highlight variations along the reservoir; however, care must be taken when interpreting features between the stations marked. Note, the black line does not give the bathymetry along the thalweg, but simply connects the maximum depth from the sounder at each station.

After the reservoir stratified (June onward), the surface layer depth and temperature were relatively uniform along the reservoir during each survey. As the summer progressed, a distinct layer of low conductivity appeared in the top 60 m in the Columbia Reach (e.g. Figures C2.1b to C2.6b for 2015). The conductivity was often lowest in Canoe Reach (e.g. Figure C1.3b). Light transmission was generally high (turbidity low) in the deep (> 60 m) water. Lenses of turbidity can be observed in the thermocline at different times and locations along the reservoir. Oxygen is generally high (e.g. Figures C1.1-6d). Chlorophyll is generally low, with peaks well below 2 μg/L in the top 20 m, just above the 1% light level (marked by black bars, e.g. Figures C1.1-6e).

3.2 Revelstoke Reservoir

In the following, the seasonal cycle for 2015 is described as sampling in 2015 began a month earlier and ended a month later than in 2014. Note that 2015 is an unusual year in terms of inflow, as the outflow from Kinbasket Reservoir was higher from April to June 2015 (blue, Figure A2.2d) compared to the low flow observed in April to June 2014 (blue, Figure A2.1d), which was more typical of the previous study years.

April to June 2015 In April, Revelstoke Reservoir was unstratified with relatively uniform temperature between 4 and 6 °C (Figure D2.1a). The conductivity was also relatively uniform (150 µS/cm), light transmission and dissolved oxygen were both uniform and high, and chlorophyll levels were generally low (Figure D2.1).

Thermal stratification was observed in mid-May, with surface temperature reaching 10 °C (Figure D2.3b). The conductivity in the upper reaches of the reservoir had declined slightly (Figure D2.3c). There were decreases in light transmission (increases in turbidity) consistent with the beginning of freshet inflow (Figure D2.3d). In addition, there was a small peak (< 1 µg/L) in chlorophyll suggesting an increase in biological activity (Figure D2.3g).

By late June, thermal stratification continued to develop with surface temperature reaching 15 °C (Figure D2.4b). The conductivity of the top 50 m of the reservoir continued to decline due to freshet inflow (Figure D2.4c) with corresponding layers of turbidity (Figure D2.4d). Chlorophyll fluorescence had small peaks just over 1 µg/L above the depth of the one percent light level (Figure D2.4g).

July to October 2015 Despite significant inflow from Kinbasket Reservoir from April to June, the conductivity of the surface layer in 2015 still declined as a result of the local freshet inflow with low conductivity (e.g. Figure D2.11c). In addition, an interflow through Revelstoke Reservoir of cold outflow water from Kinbasket Reservoir is also observed in 2015 (e.g. Figure E2.4b), although it appeared earlier than in previous years.

From mid-July to September, changes in the reservoir were dominated by the inflow from Mica; this inflow was both cool and higher in conductivity than the surface of Revelstoke Reservoir. In the 20-23 July 2015 profiles, the effect of the Kinbasket inflow can be seen at all stations from 15 to 60 m depth, composed of water from 8-11 °C and with a conductivity of around 130 µS/cm (Figure D2.5b,c). By mid-September, the interflow has almost reached the surface (Figure E2.7b).

Comparison of casts in the forebay (e.g. Figure D2.11) indicate slight changes to the deep water (> 60 m) throughout the summer, with a slight increase in temperature and a decrease in conductivity, likely due to a small degree of exchange with overlying water. The decrease in oxygen over the summer was <2 mg/L.

4. Discussion

Trophic Status

As an indicator of trophic status, Wetzel (2001) gives the following general ranges for chlorophyll concentrations:

- 0.05-0.5 μg/L ultraoligotrophic;
- 0.3-3 μg/L oligotrophic; and
- 2-15 μg/L mesotrophic.

The low concentrations of chlorophyll in both Kinbasket and Revelstoke Reservoirs (<2 nominal μg/L) are consistent with oligotrophic conditions.

The reduction in hypolimnetic oxygen over the summer was low in both Kinbasket (<1 mg/L) and Revelstoke Reservoirs (<2 mg/L). The use of hypolimnetic oxygen demand as an indicator of trophic status comes with a number of caveats (Wetzel 2001), including the problem of decomposing allochthonous debris. The declines in hypolimnetic oxygen over the summer in Kinbasket and Revelstoke Reservoirs are consistent with oligotrophy, and are comparable to those observed in oligotrophic Harrison Lake (0.3 mg/L, Pieters et al. 2002) and Coquitlam Reservoir (1.5 mg/L, Pieters et al. 2007).

Circulation and nutrients

Both Kinbasket and Revelstoke Reservoirs display unusually broad and deep thermoclines. Typically, thermal structure in summer is dominated by surface heat fluxes and wind. The thermal structure observed in Kinbasket and Revelstoke Reservoirs suggests that the deep outlets (32 to 65 m in Kinbasket and 28 m in Revelstoke), high inflow, and short residence time (< 1 yr) may also be important.

The variation in the conductivity of the tributary inflows provides a tracer to identify water masses. Both Kinbasket and Revelstoke Reservoirs have a surface layer of reduced conductivity, which suggests surface waters contain a significant fraction of freshet inflow.

Based on the given data we can tentatively sketch the circulation of Kinbasket and Revelstoke Reservoirs and speculate on the supply of nitrate. As described in Pieters et al. (2017a), late spring and summer can be broken into two periods based on flow: May to June, and July to September. In the first period of May and June, the top 30 m of Kinbasket Reservoir is filled with freshet inflow and there is little outflow from Mica Dam (Figure A2.1c), to which 2015 is an exception (Figure A2.2c). The lack of outflow from Mica Dam means that the circulation in Revelstoke Reservoir is dominated by local inflow during this time (Figure A2.1d). During the second period of July to September, the tail of the freshet is passed through Mica and, in Revelstoke Reservoir, this water forms an interflow directly to the outlet at Revelstoke Dam (e.g. Figures E1.4b). This interflow appears to be below the photic zone (Figure E1.4e). If this occurs, nutrients from Mica will short circuit below the photic zone until fall cooling mixes the interflow into the surface layer later in October. However, profiler data - for example, from mid-September to mid-October 2012 (Pieters and Lawrence 2014b) - suggests that internal wave motions can bring the interflow into the photic zone for significant periods of time. Another example is 14-15 October 2014 when the stratification was weak, the internal deflections were large, and part of the interflow (Figure E1.6b) was in the photic zone (Figure E1.6e).

Acknowledgements

Profiles were collected by B. Manson, P. Bourget and K. Bray. We gratefully acknowledge funding provided by B.C. Hydro. We thank A. Baysheva, J. Bowman, A. Sharp, K. Lywe, T. Rodgers, A. Law, and A. Quainoo for assistance with data processing, and the UBC Work-Learn program for salary subsidy. We thank R. Pawlowicz for helpful discussions of instruments and data.

References

Fleming, J.O. and H.A. Smith. 1988. Revelstoke Reservoir aquatic monitoring program, 1986, progress report. B.C. Hydro Report No. ER 88-03.

Pieters, R., R. Pawlowicz, and G. A. Lawrence. 2002. Harrison Lake Hydrographic Surveys, November 2000 – April 2002. Prepared for Dayton and Knight Ltd. and the Fraser Valley Regional District, September 2002. 102 pp.

Pieters, R., L.C. Thompson, L. Vidmanic, S. Harris, J. Stockner, H. Andrusak, M. Young, K. Ashley, B. Lindsay, G. Lawrence, K. Hall, A. Eskooch, D. Sebastian, G. Scholten and P.E. Woodruff. 2003. Arrow Reservoir fertilization experiment, year 2 (2000/2001) report. RD 87, Fisheries Branch, Ministry of Water, Land and Air Protection, Province of British Columbia.

Pieters, R., G. Lawrence, R. Pawlowicz, and M. Rahmani. 2007. Lake Processes and Turbidity, Coquitlam Reservoir 2004 & 2005. Prepared for Utility Analysis and Environmental Management Division, Policy and Planning Department, Greater Vancouver Regional District, March 2007. 143 pp.

Pieters, R., and G. Lawrence. 2014a. CTD Surveys, Kinbasket and Revelstoke Reservoirs, 2012. 55 pp. Appendix 3 in Bray K. 2014. Kinbasket and Revelstoke Reservoirs Ecological Productivity Monitoring. Progress Report Year 5 (2012). BC Hydro, Environment. Study No. CLBMON-3.

Pieters, R., and G. Lawrence. 2014b. Moorings, Kinbasket and Revelstoke Reservoirs, 2012. 15 pp. Appendix 3 in Bray K. 2014. Kinbasket and Revelstoke Reservoirs Ecological Productivity Monitoring. Progress Report Year 5 (2012). BC Hydro, Environment. Study No. CLBMON-3.

Pieters, R., and G. Lawrence. 2017a. Hydrology of Kinbasket and Revelstoke Reservoirs, 2014 and 2015. 59 pp. Appendix 1 in Bray K. 2017. Kinbasket and Revelstoke Reservoirs Ecological Productivity Monitoring. Progress Report Year 7 and 8 (2014 and 2015). BC Hydro, Environment. Study No. CLBMON-3.

Pieters, R., and G. Lawrence. 2017b. Tributary Water Quality, Kinbasket and Revelstoke Reservoirs, 2014 and 2015. 30pp. Appendix 2 in Bray K. 2017. Kinbasket and Revelstoke Reservoirs Ecological Productivity Monitoring. Progress Report Year 7 and 8 (2014 and 2015). BC Hydro, Environment. Study No. CLBMON-3.

Watson, T.A. 1985. Revelstoke Project Water Quality Studies 1978-1984. B.C. Hydro Report No. ESS-108, Jul 1985. 237pp.

Wetzel, R.G. 2001. Limnology. Academic Press, San Diego.

Figure A1 Map showning approximate location of profile stations

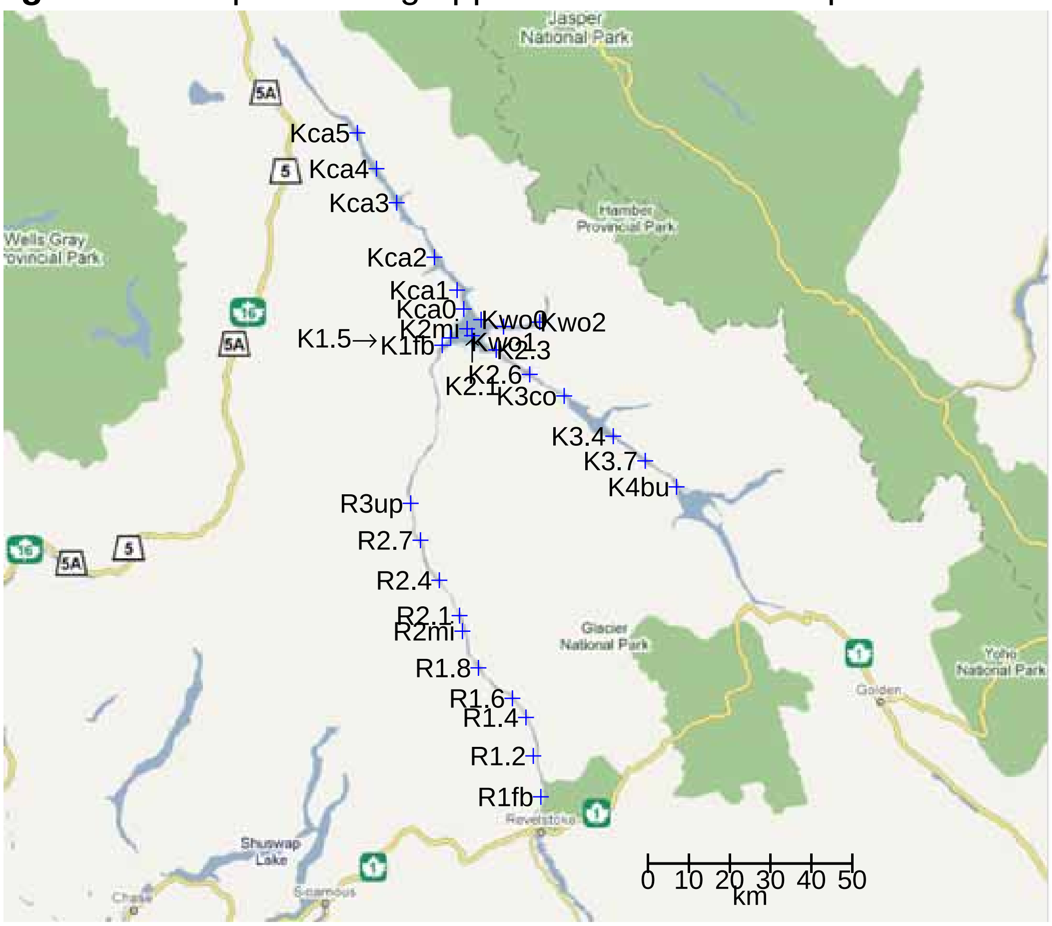


Figure A2.1 Water level and flow, Kinbasket and Revelstoke Reservoirs, 2014

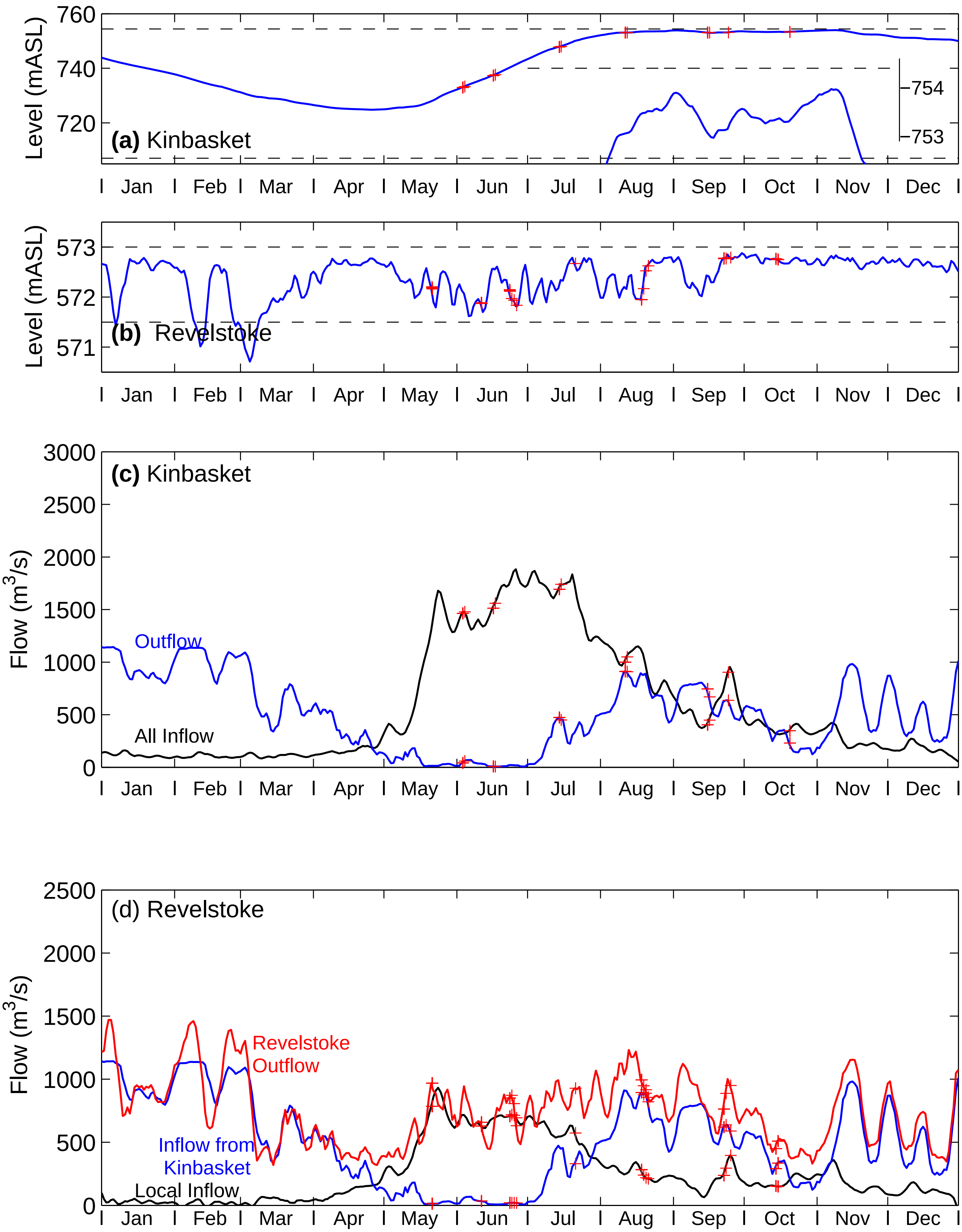


Figure A2.2 Water level and flow, Kinbasket and Revelstoke Reservoirs, 2015

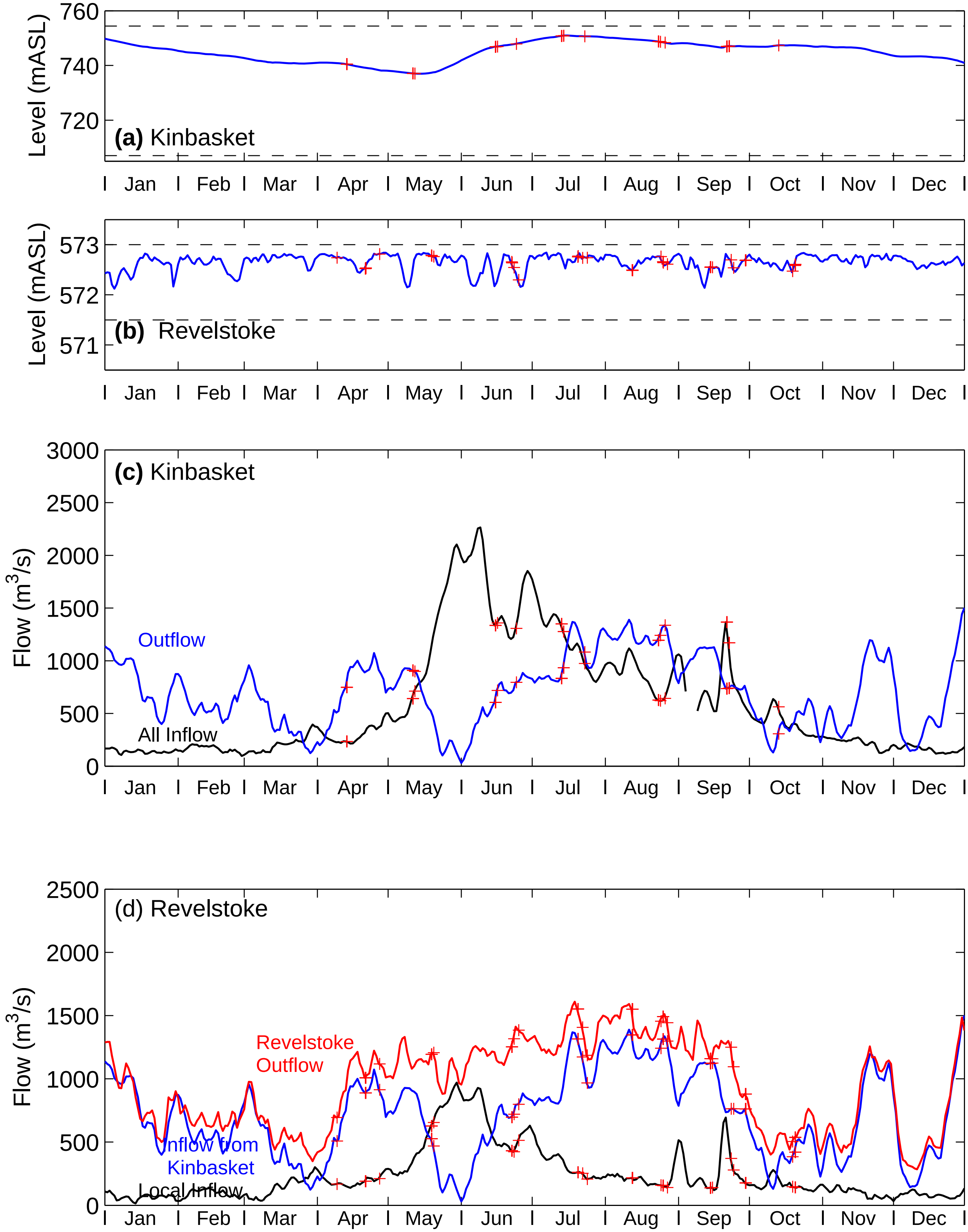
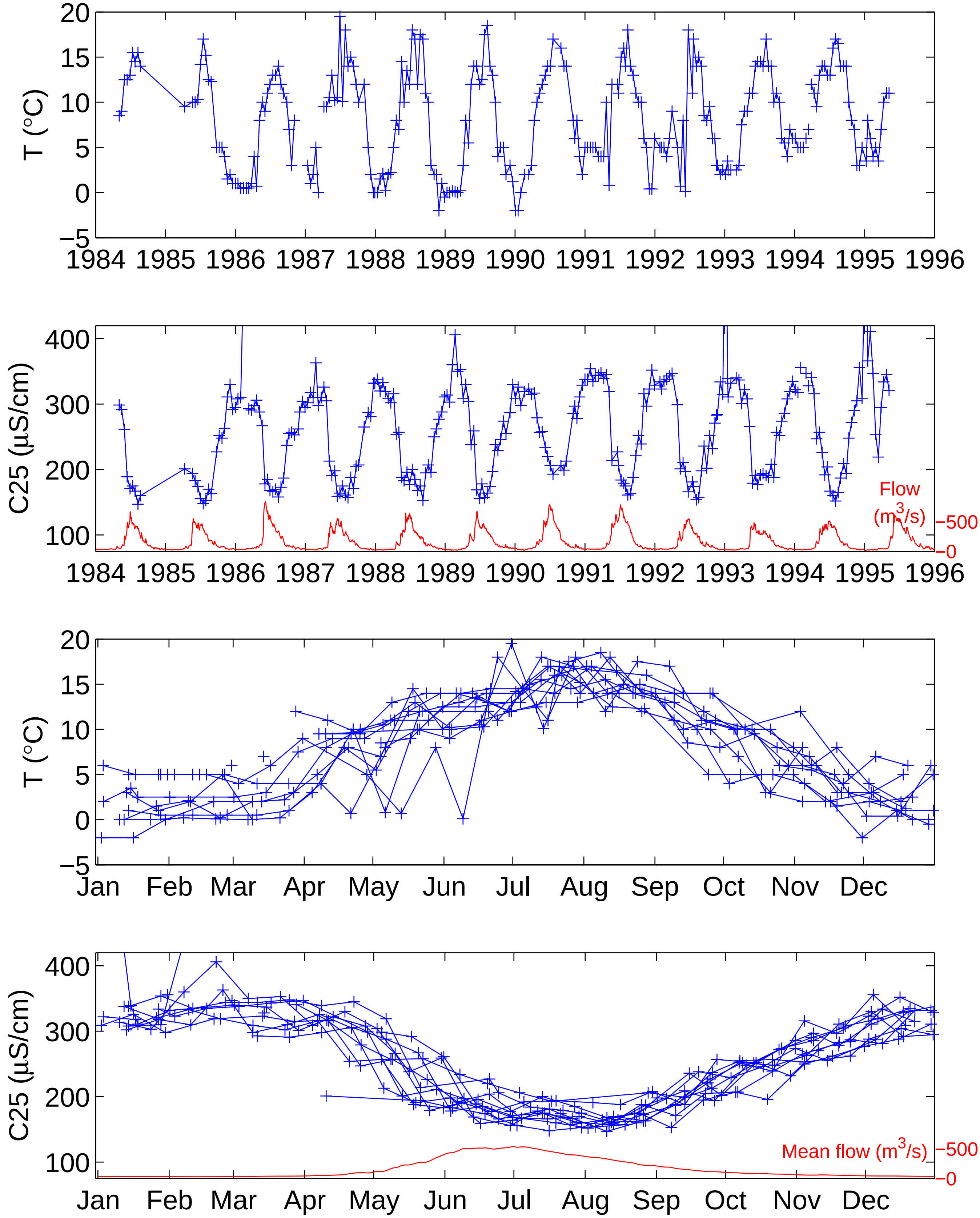


Figure A3 Columbia River at Donald, T and C25, 1984−1995



/ocean/rpieters/kr/flow/ecan/plot/plotcoldo.m fig= 1 2009−Jun−01

Figure A4 1% Light Level = 2.5 X Secchi Depth

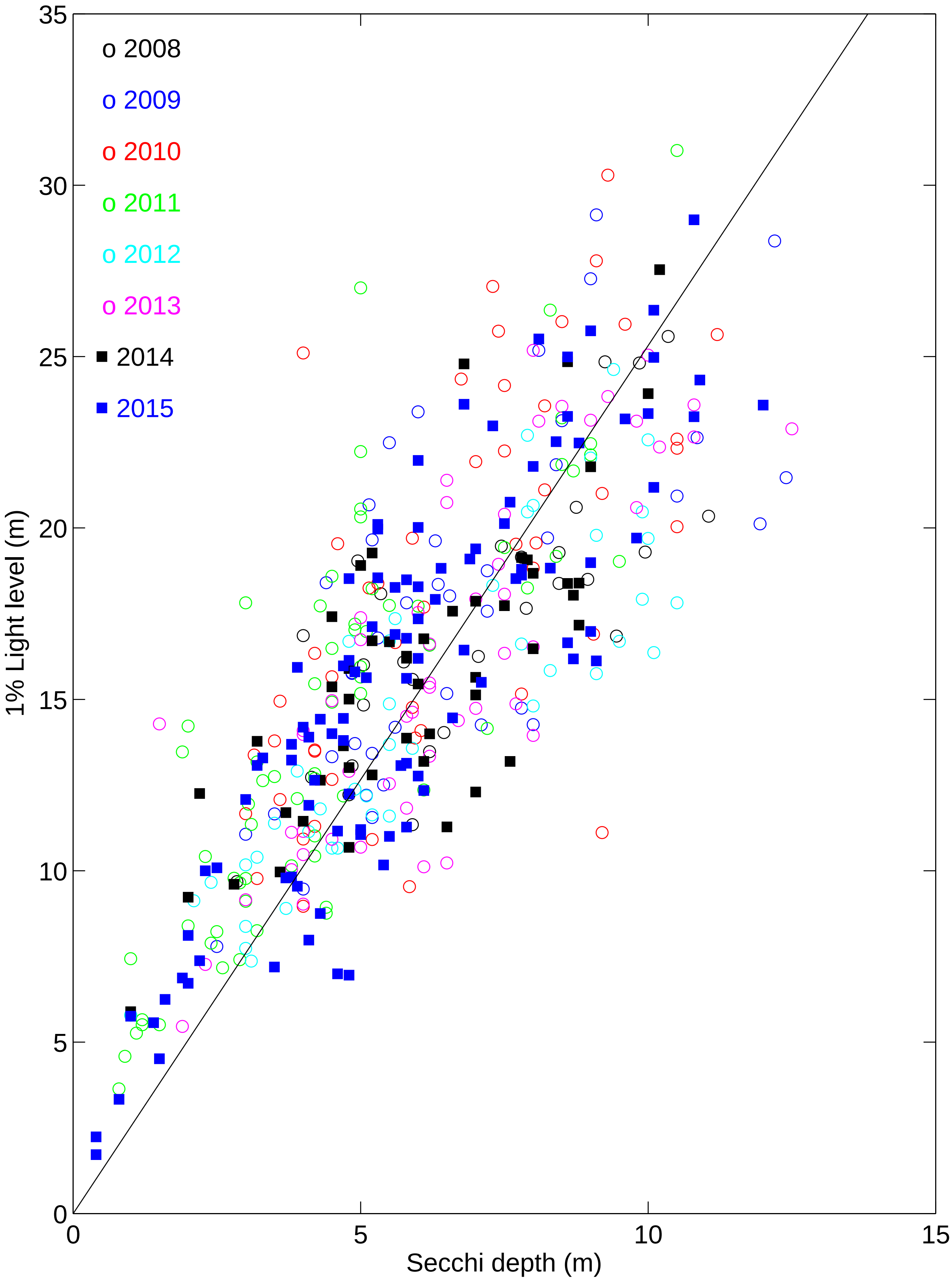


Figure B1.1 Kinbasket Reservoir, 3−4 Jun 2014

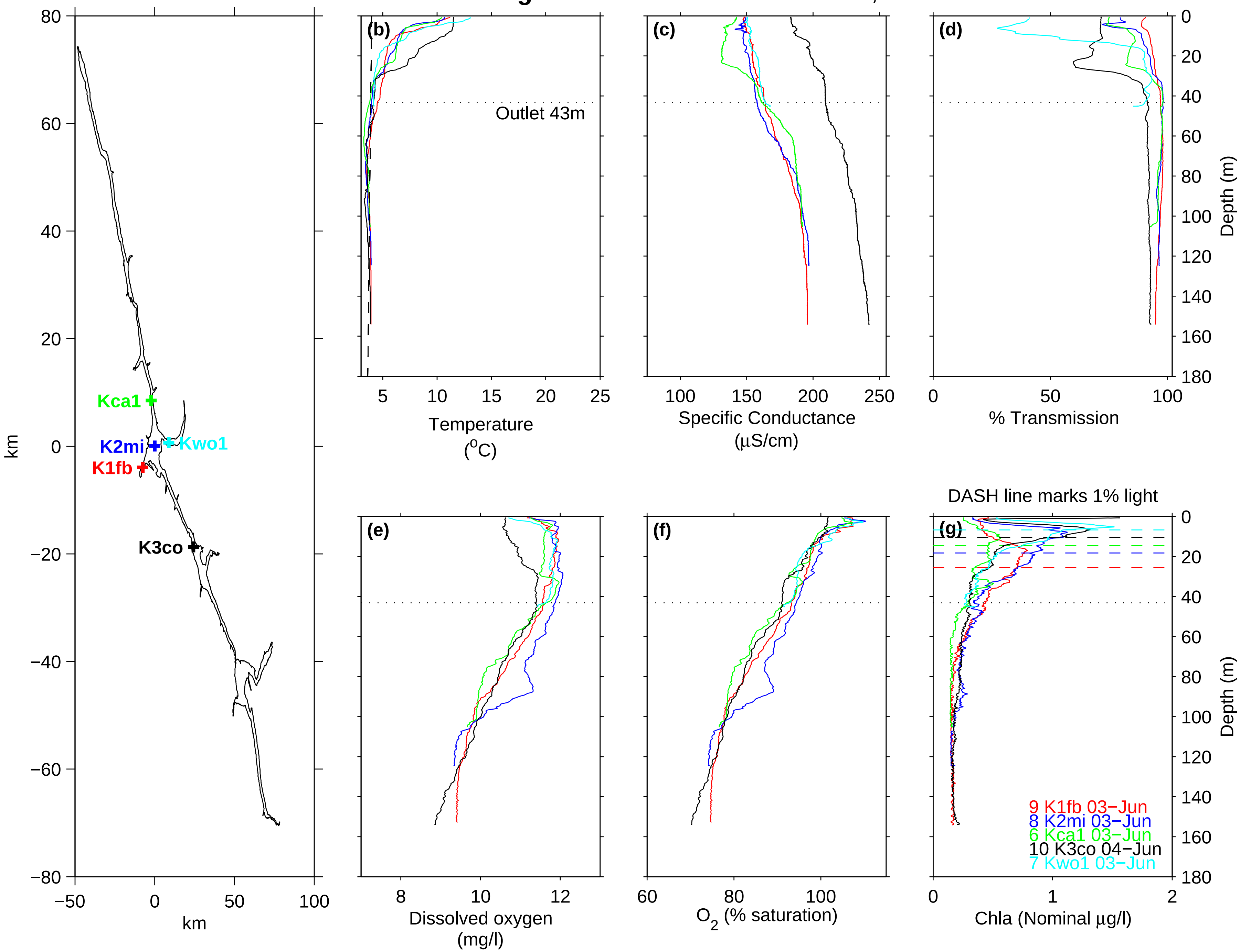


Figure B1.2 Kinbasket Reservoir, 16−17 Jun 2014

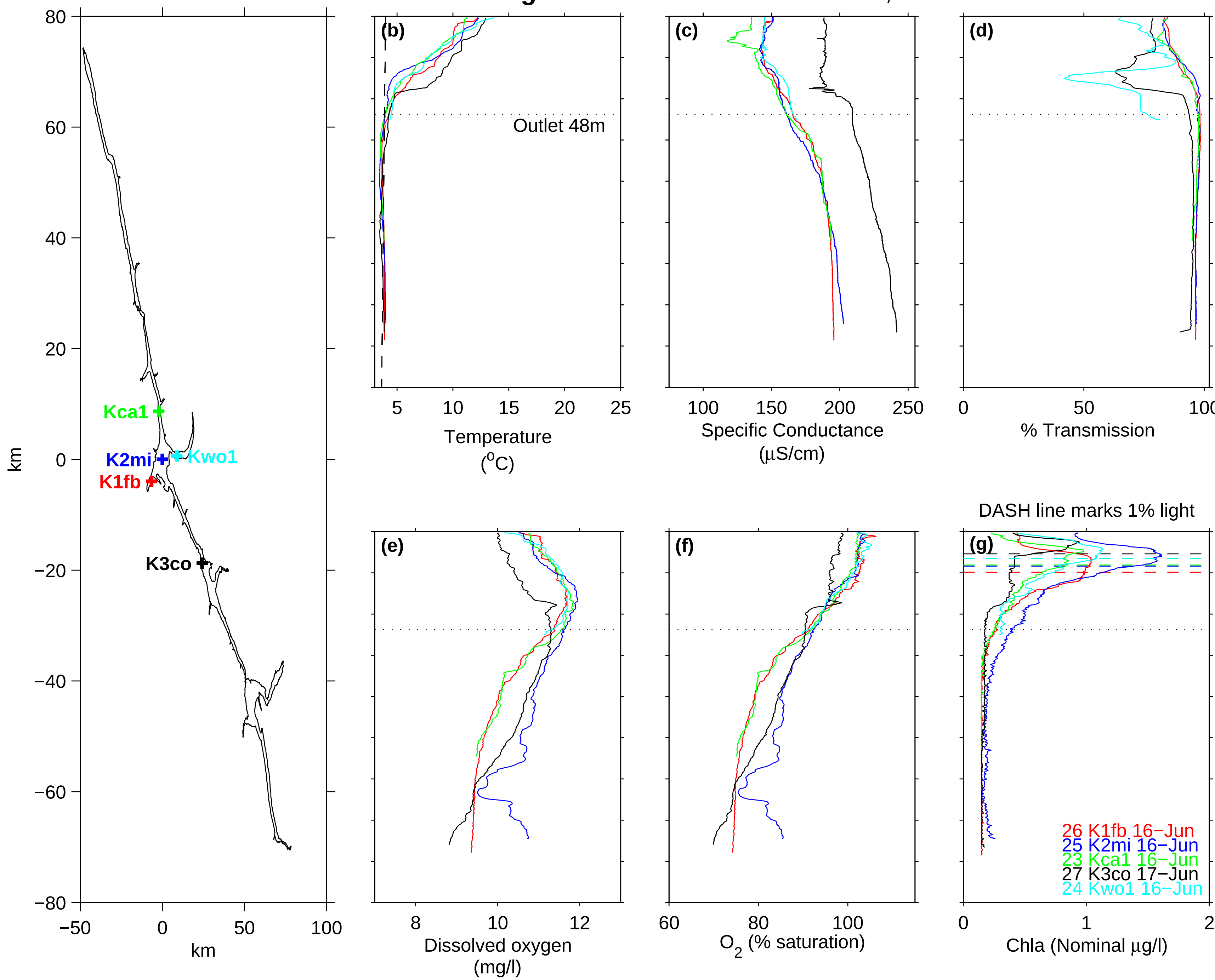


Figure B1.3 Kinbasket Reservoir, 14−15 Jul 2014

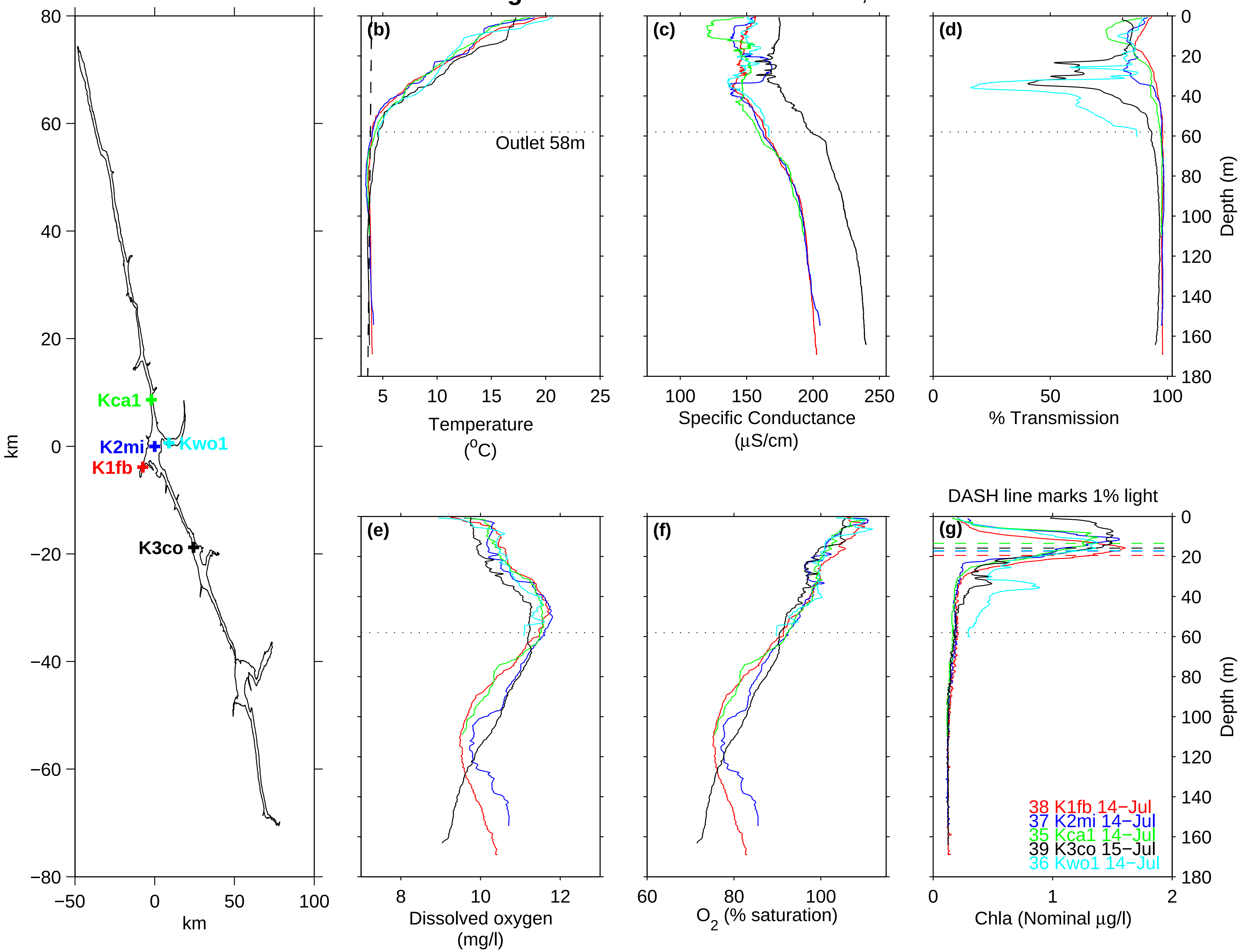


Figure B1.4 Kinbasket Reservoir, 11−12 Aug 2014

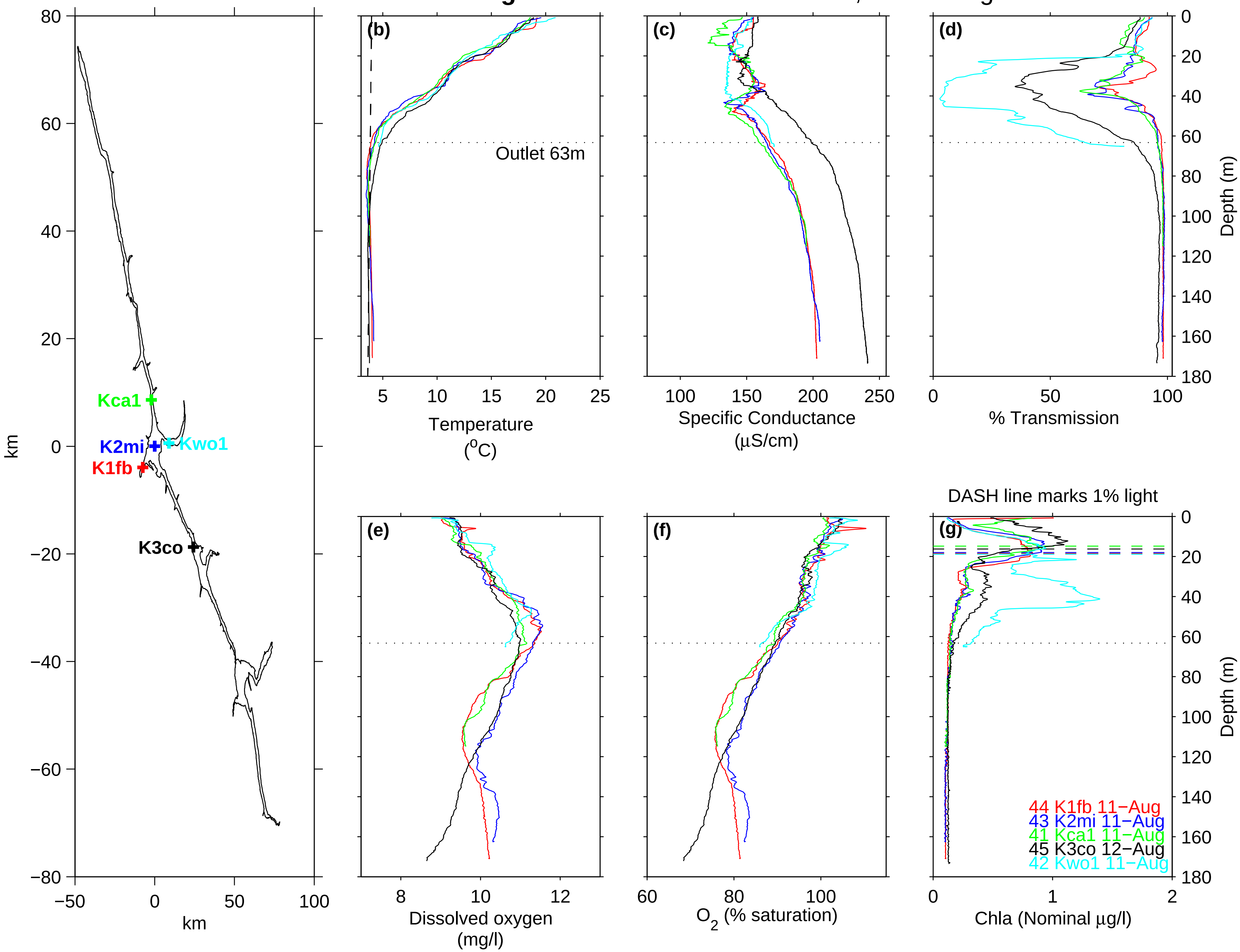


Figure B1.5 Kinbasket Reservoir, 15−16 Sep 2014

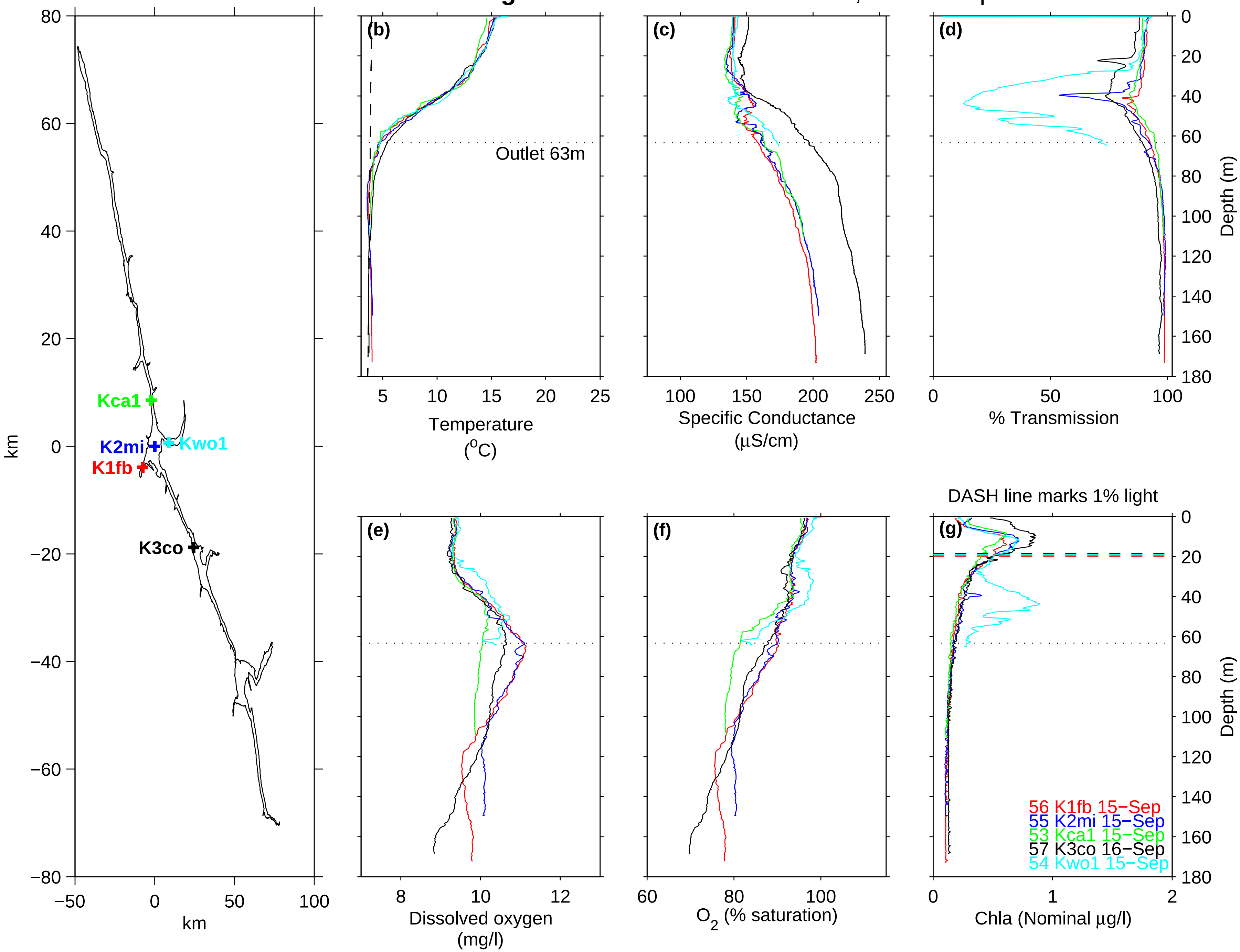


Figure B1.6 Kinbasket Reservoir, 20 Oct 2014

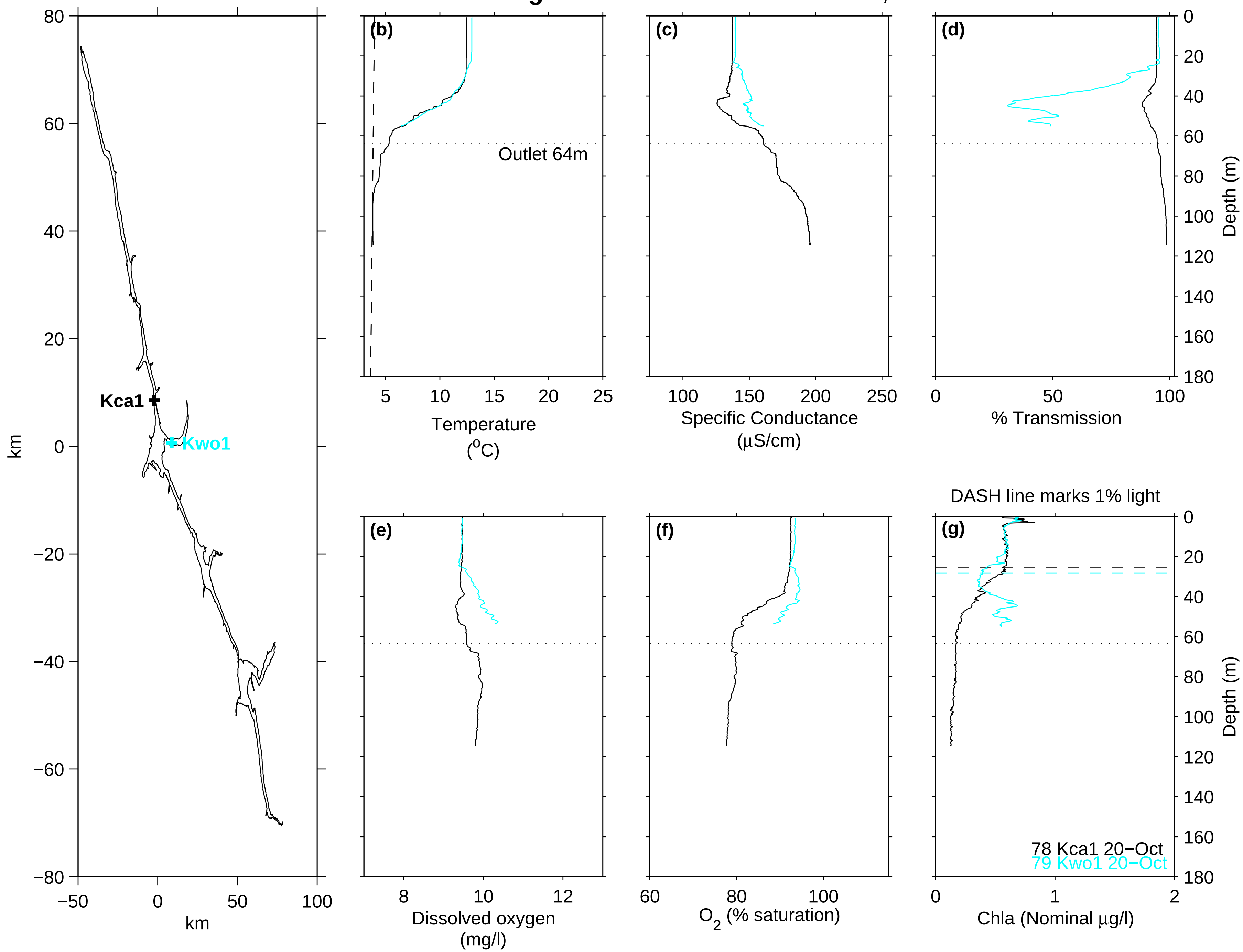


Figure B1.7 Kinbasket Reservoir, Forebay, K1fb, 2014

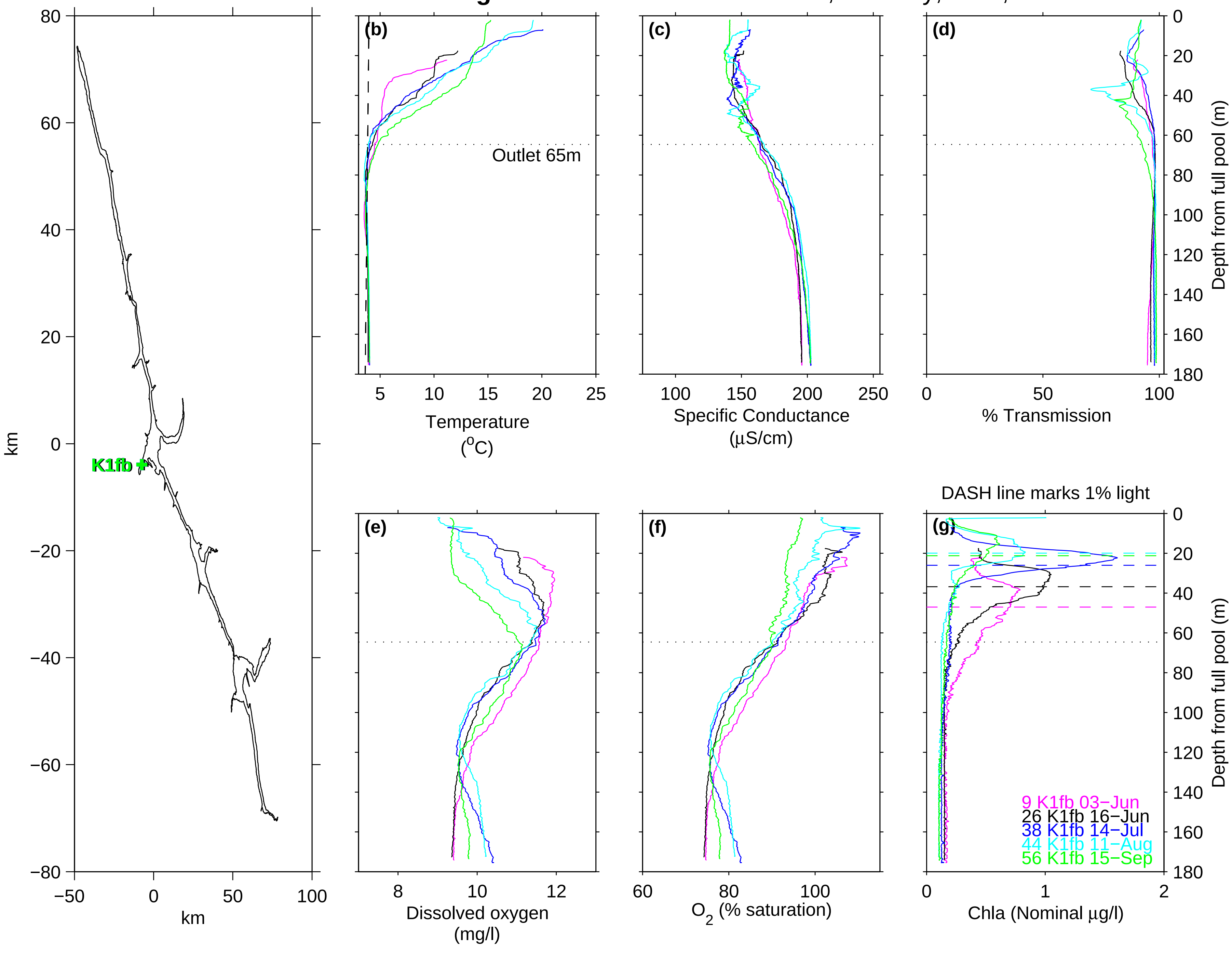


Figure B1.8 Kinbasket Reservoir, Middle, K2mi, 2014

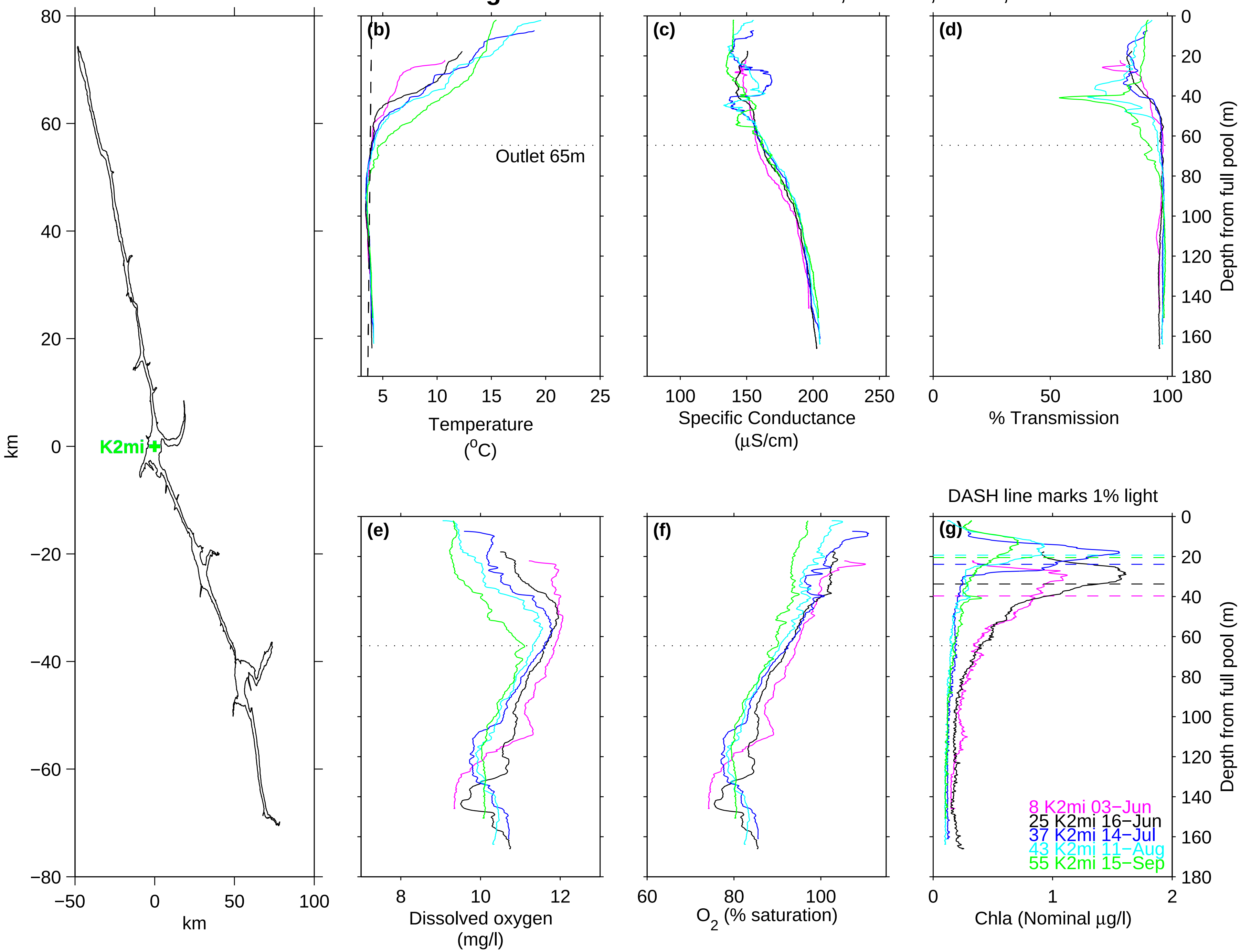


Figure B1.9 Kinbasket Reservoir, Columbia, K3co, 2014

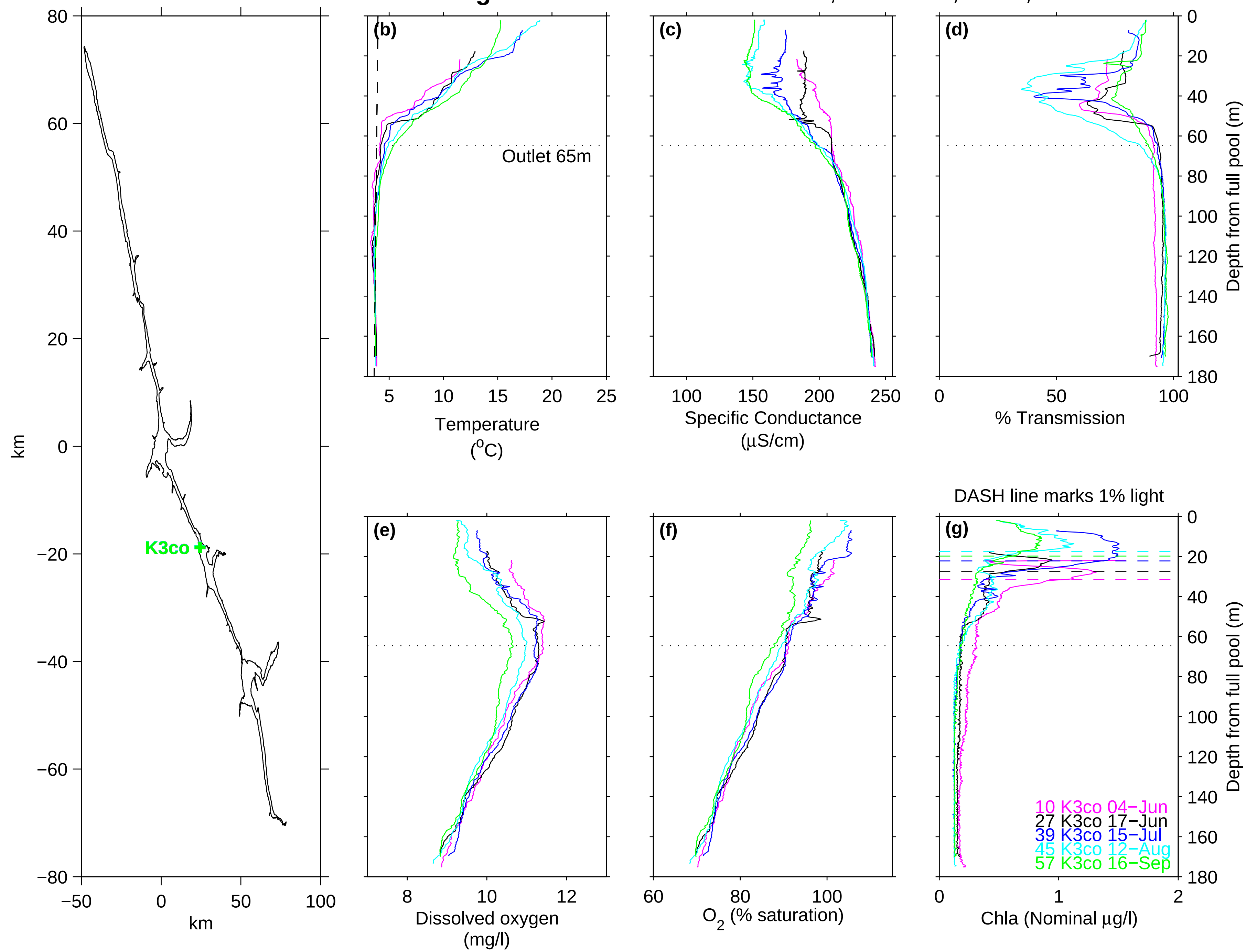


Figure B1.10 Kinbasket Reservoir, Canoe, Kca1, 2014

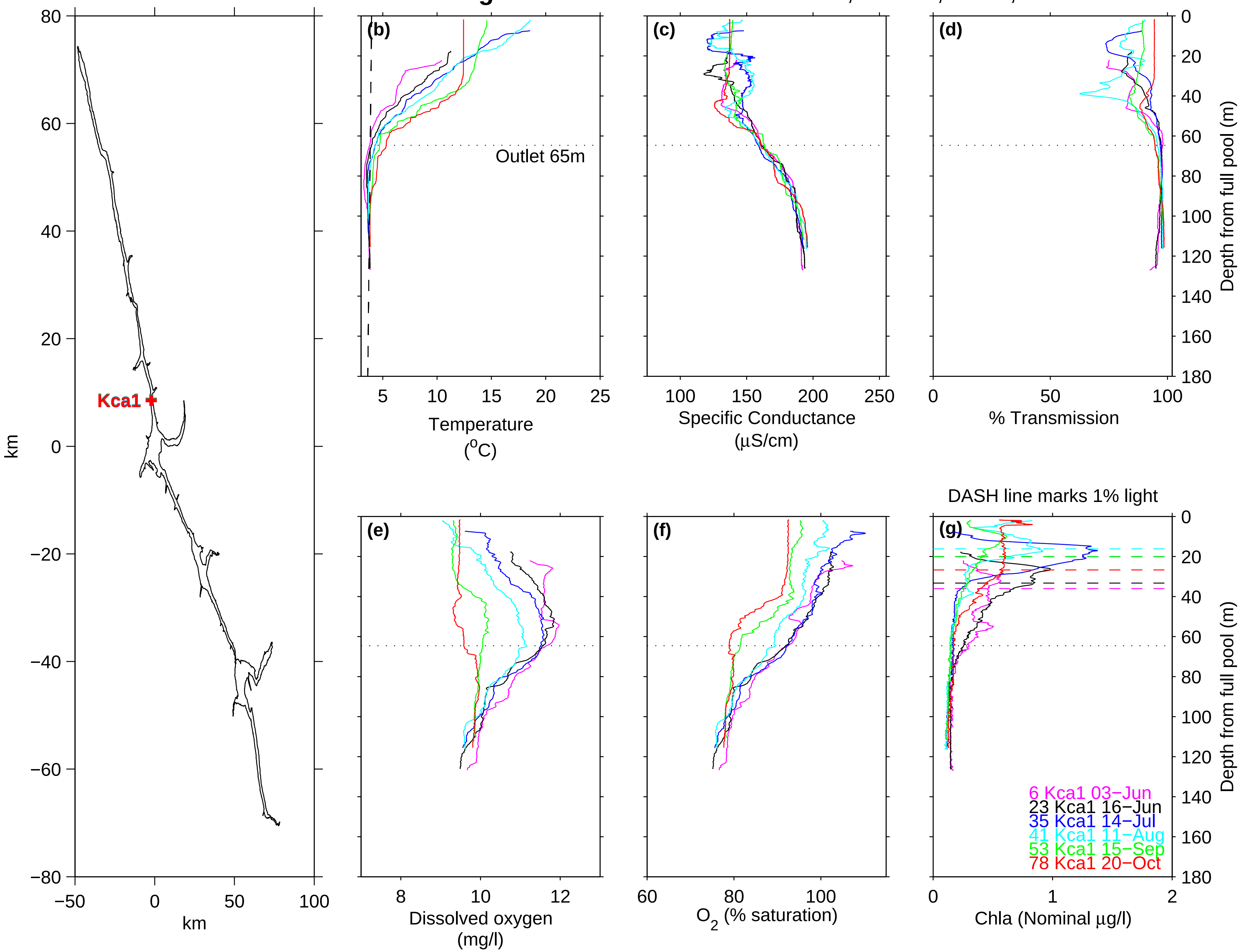


Figure B1.11 Kinbasket Reservoir, Wood, Kwo1, 2014

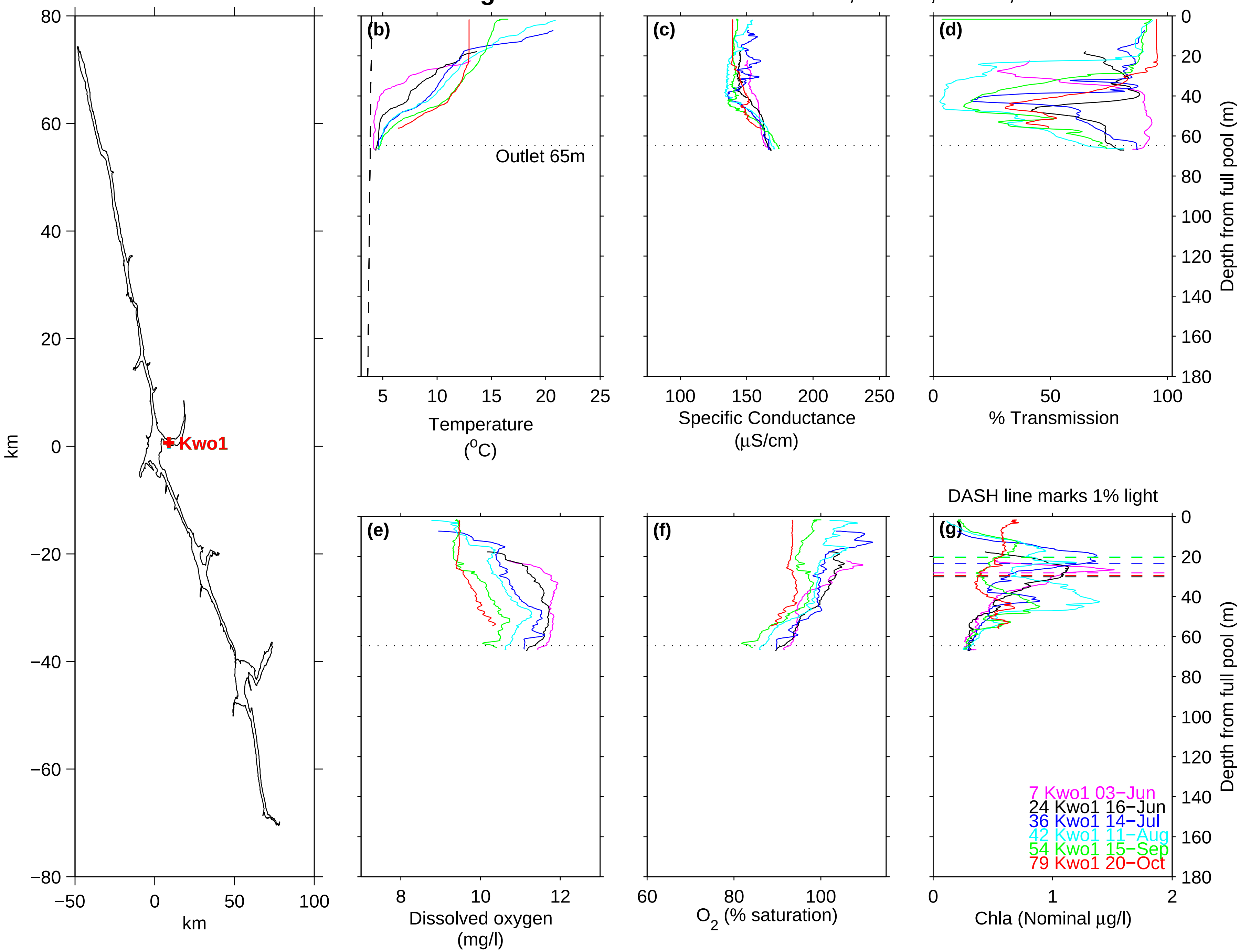


Figure B2.1 Kinbasket Reservoir, 13 Apr 2015

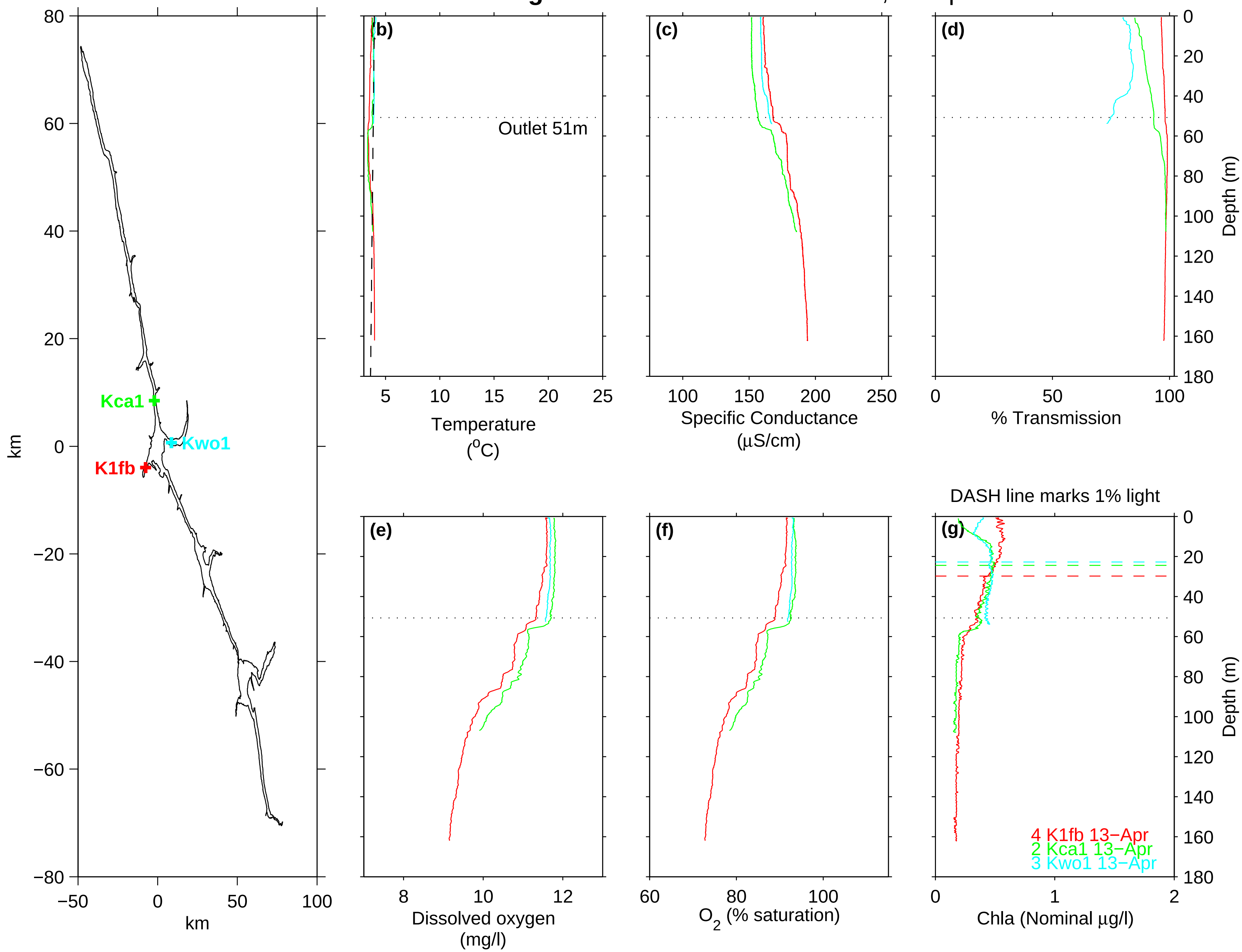


Figure B2.2 Kinbasket Reservoir, 11−12 May 2015

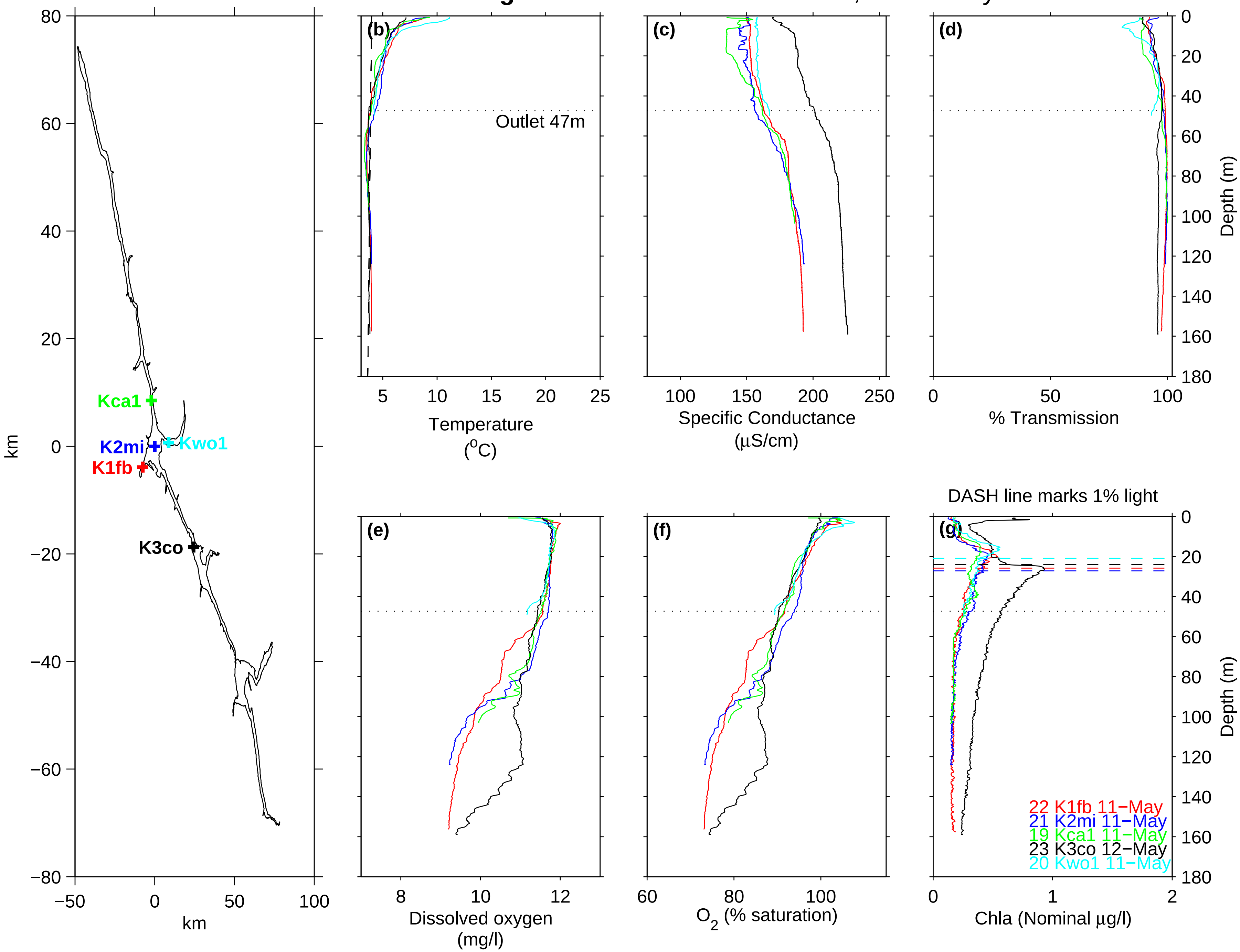


Figure B2.3 Kinbasket Reservoir, 15−16 Jun 2015

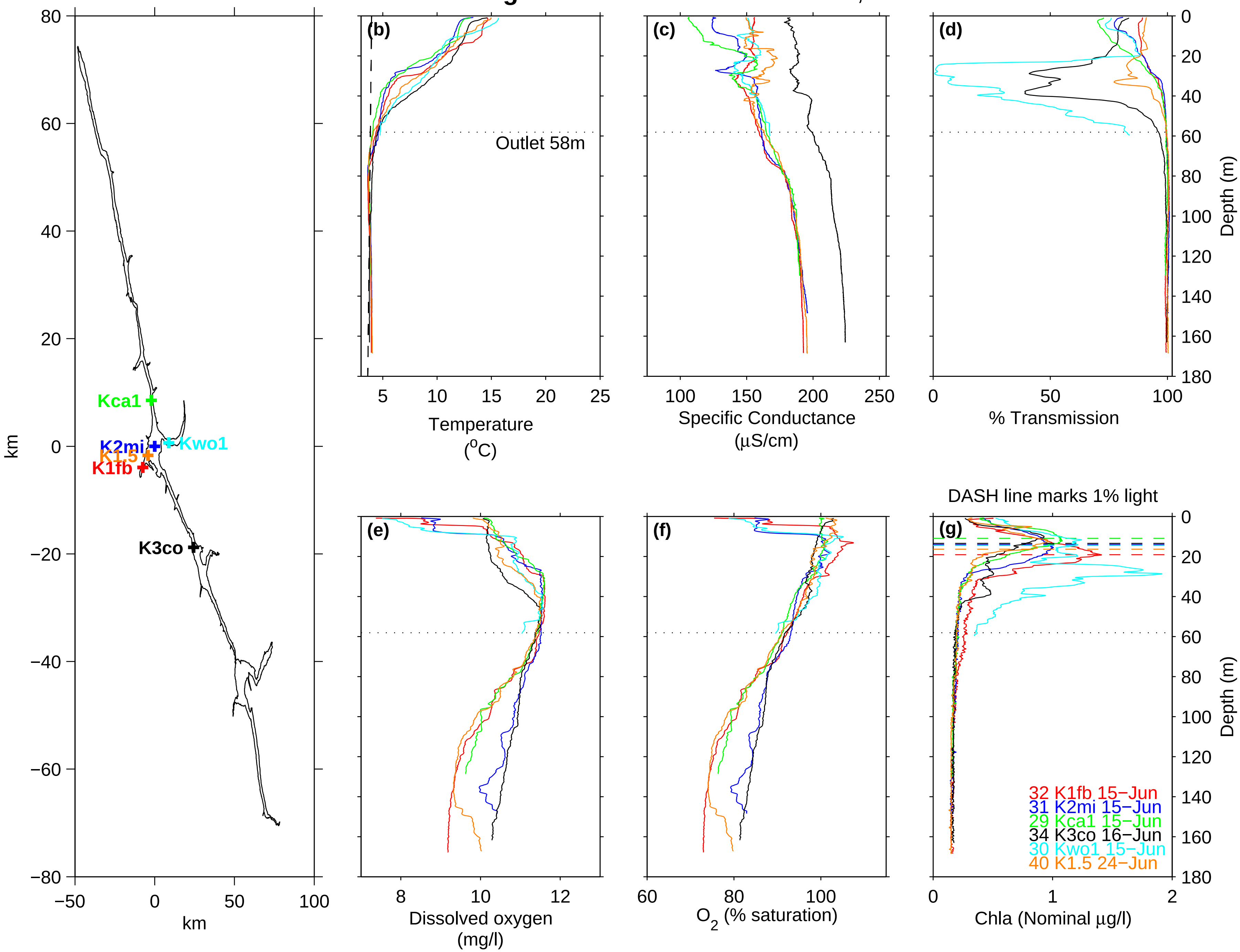


Figure B2.4 Kinbasket Reservoir, 13−14 Jul 2015

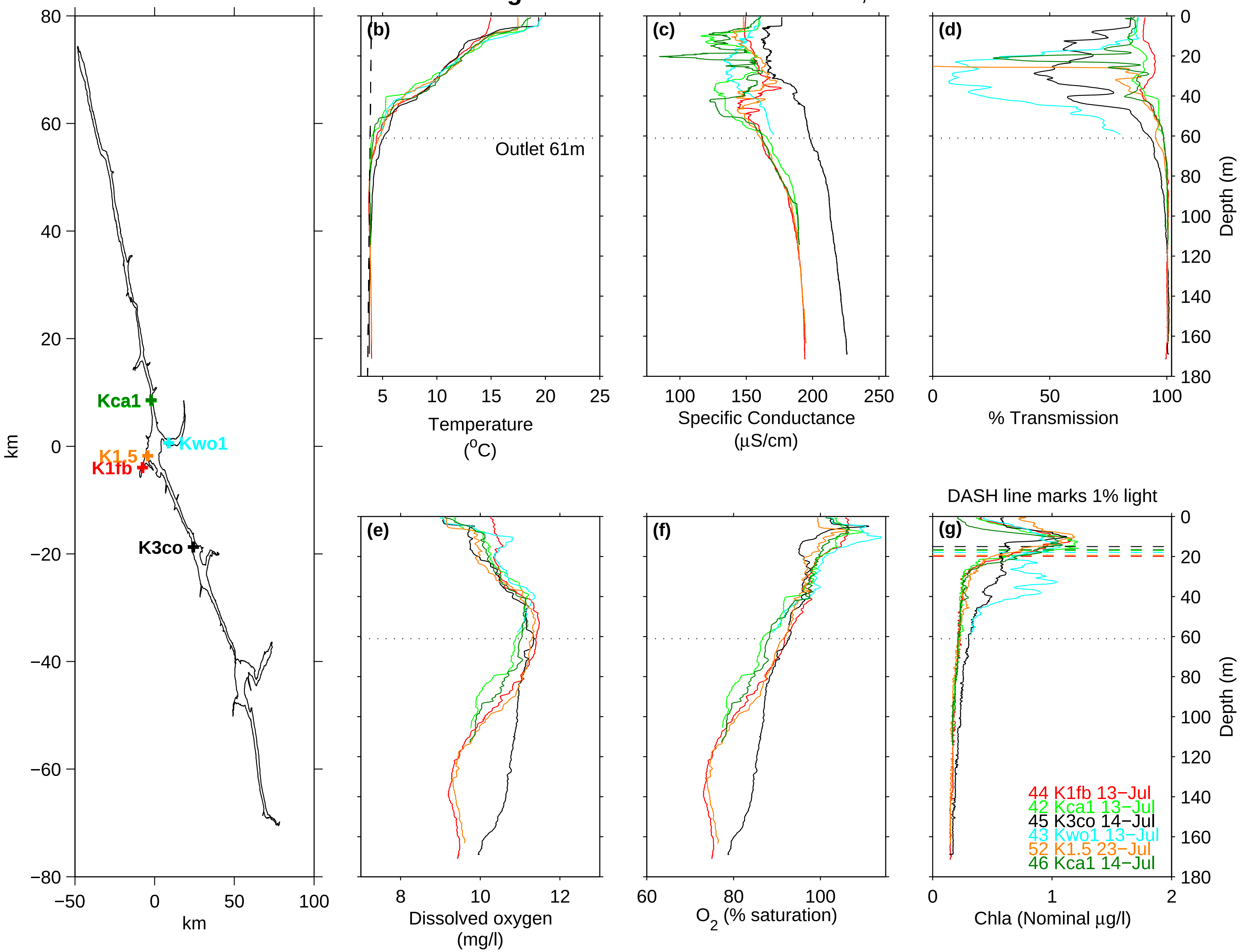


Figure B2.5 Kinbasket Reservoir, 23−24 Aug 2015

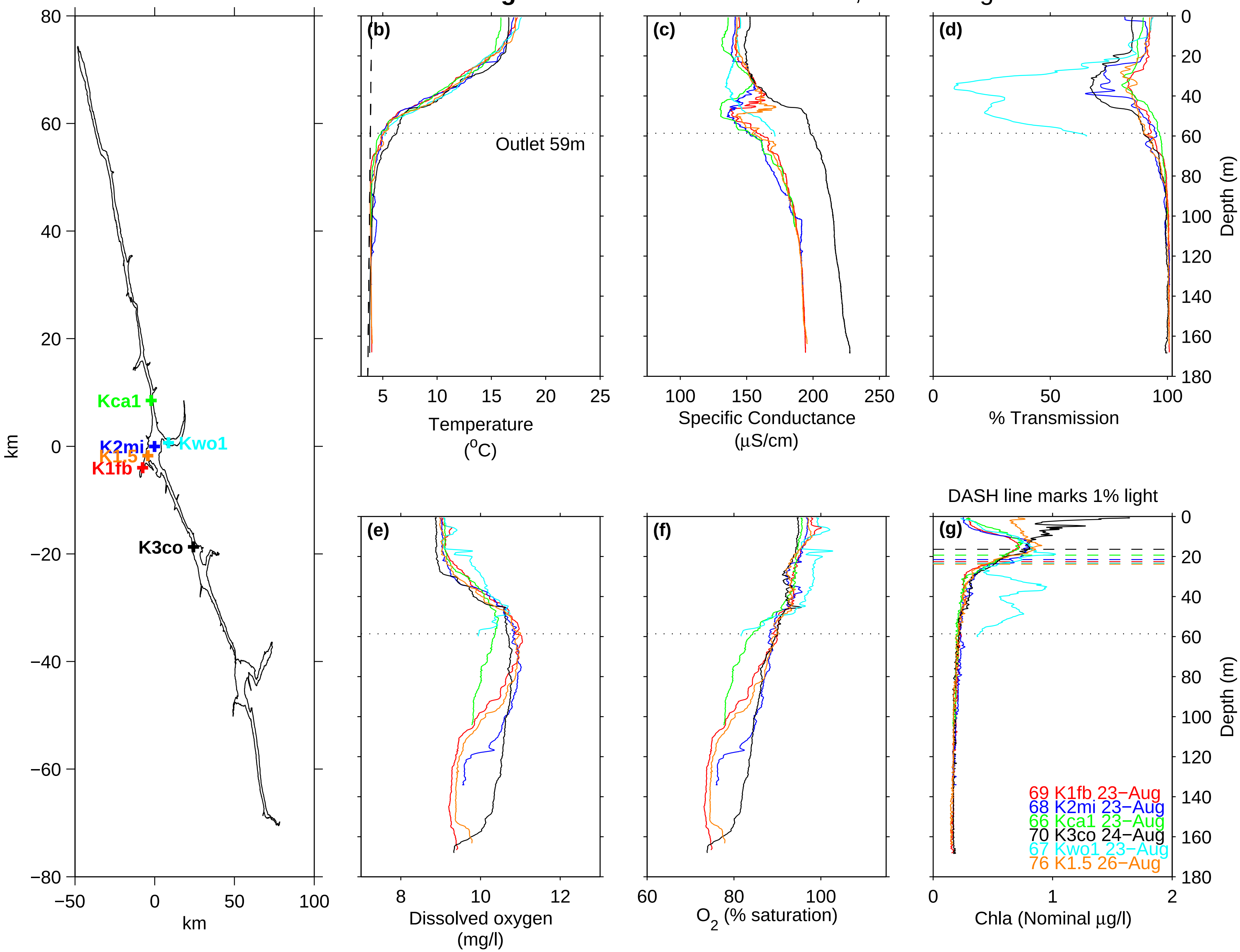


Figure B2.6 Kinbasket Reservoir, 21−22 Sep 2015

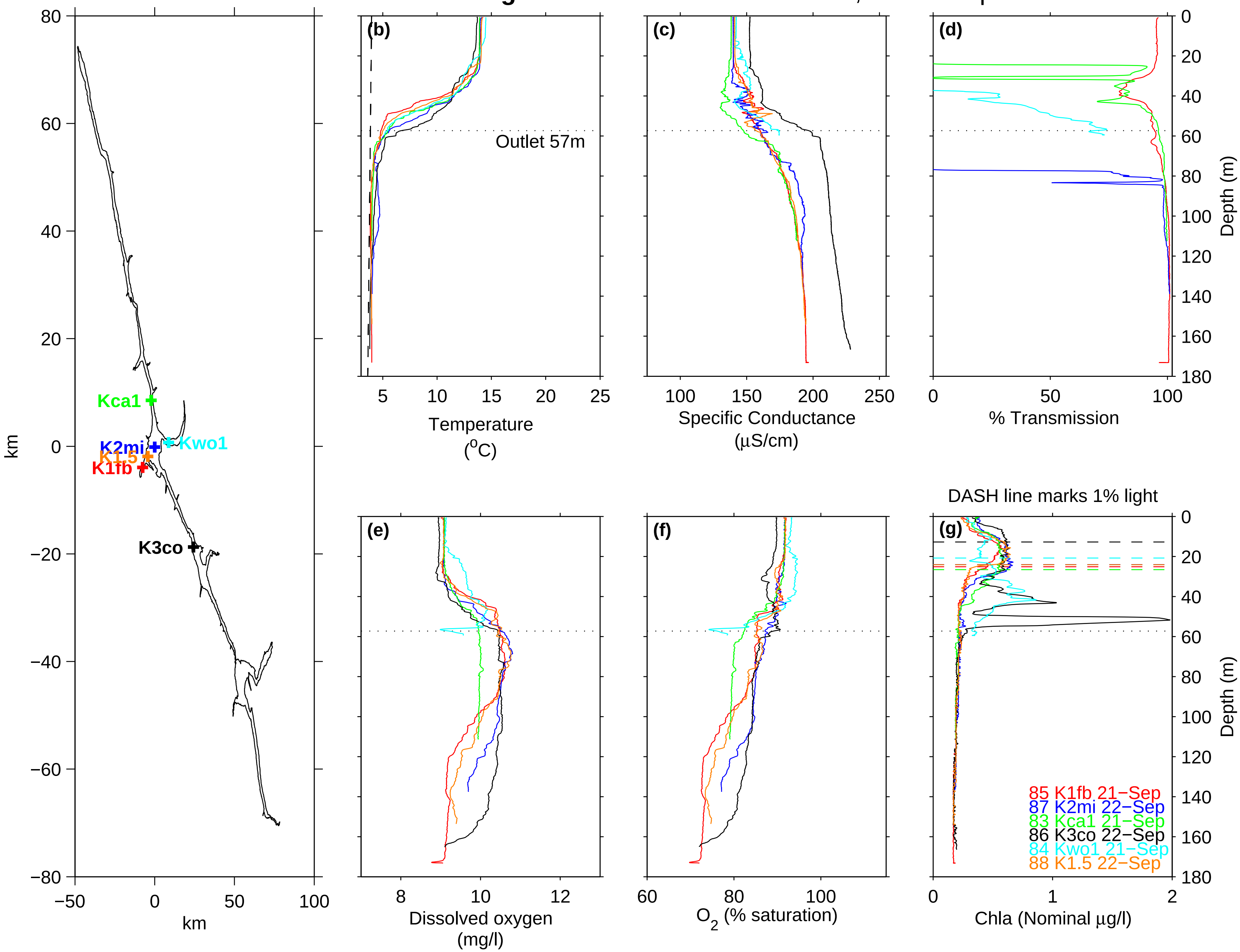


Figure B2.7 Kinbasket Reservoir, 20 Oct 2015

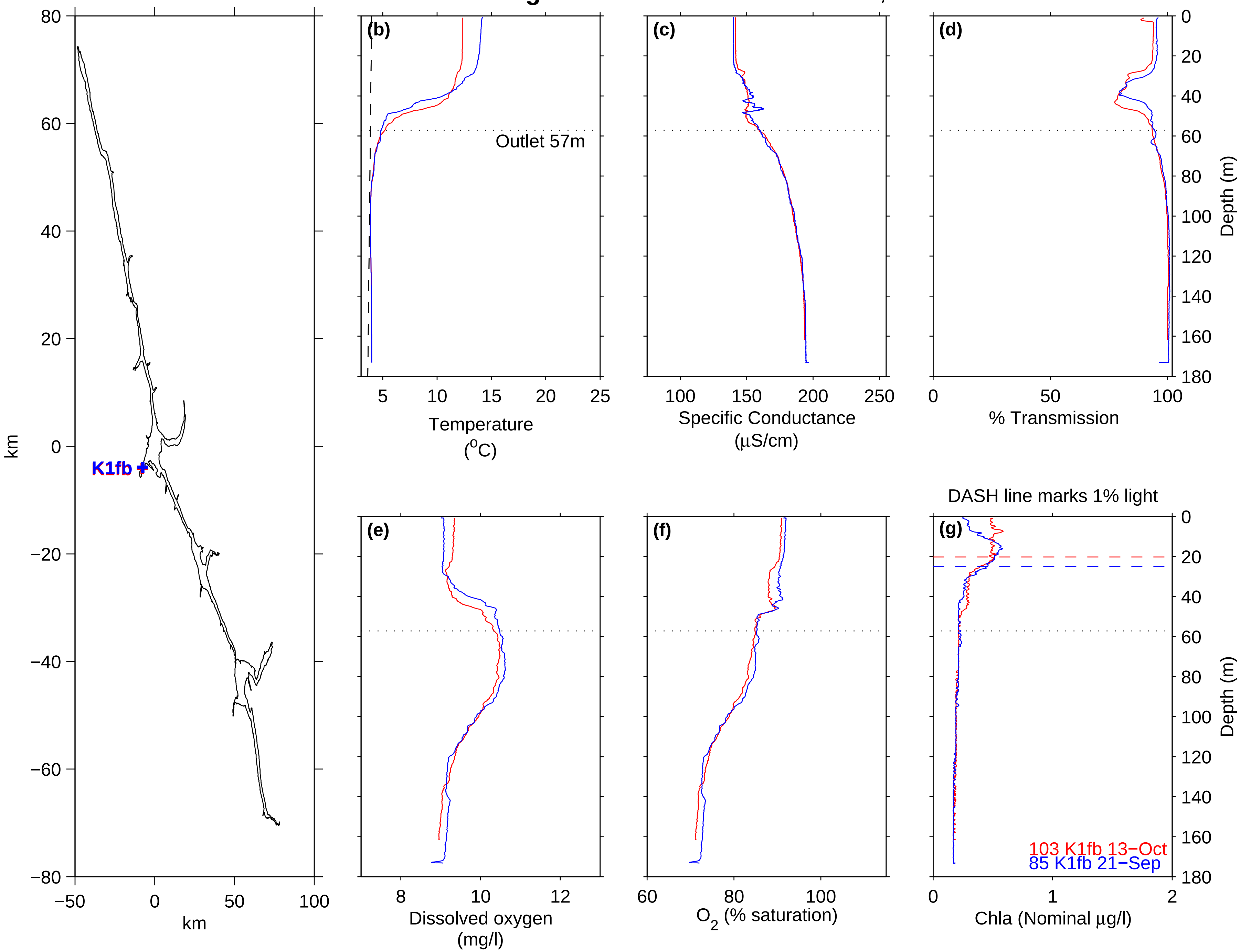


Figure B2.8 Kinbasket Reservoir, Forebay, K1fb, 2015

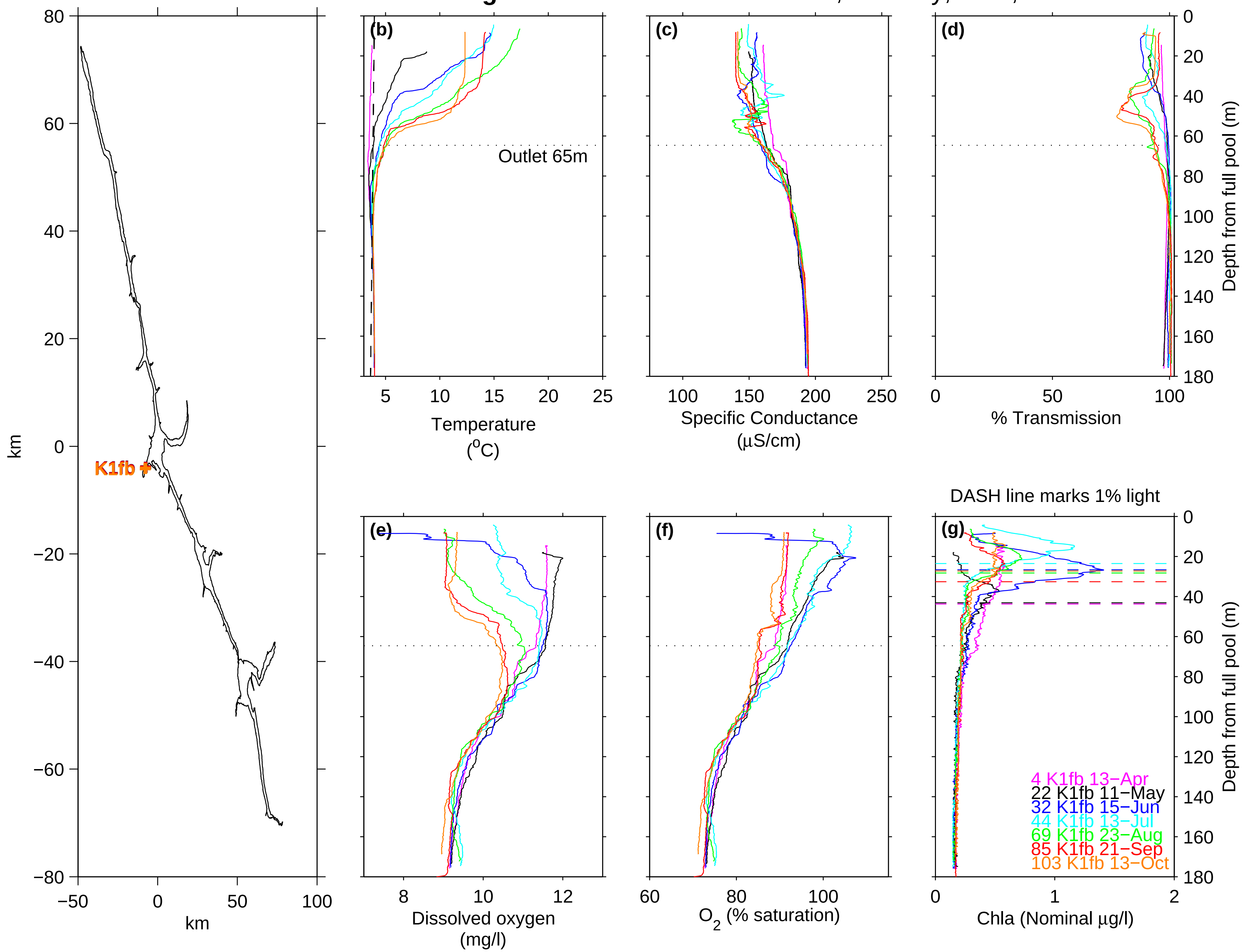


Figure B2.9 Kinbasket Reservoir, Middle, K2mi, 2015

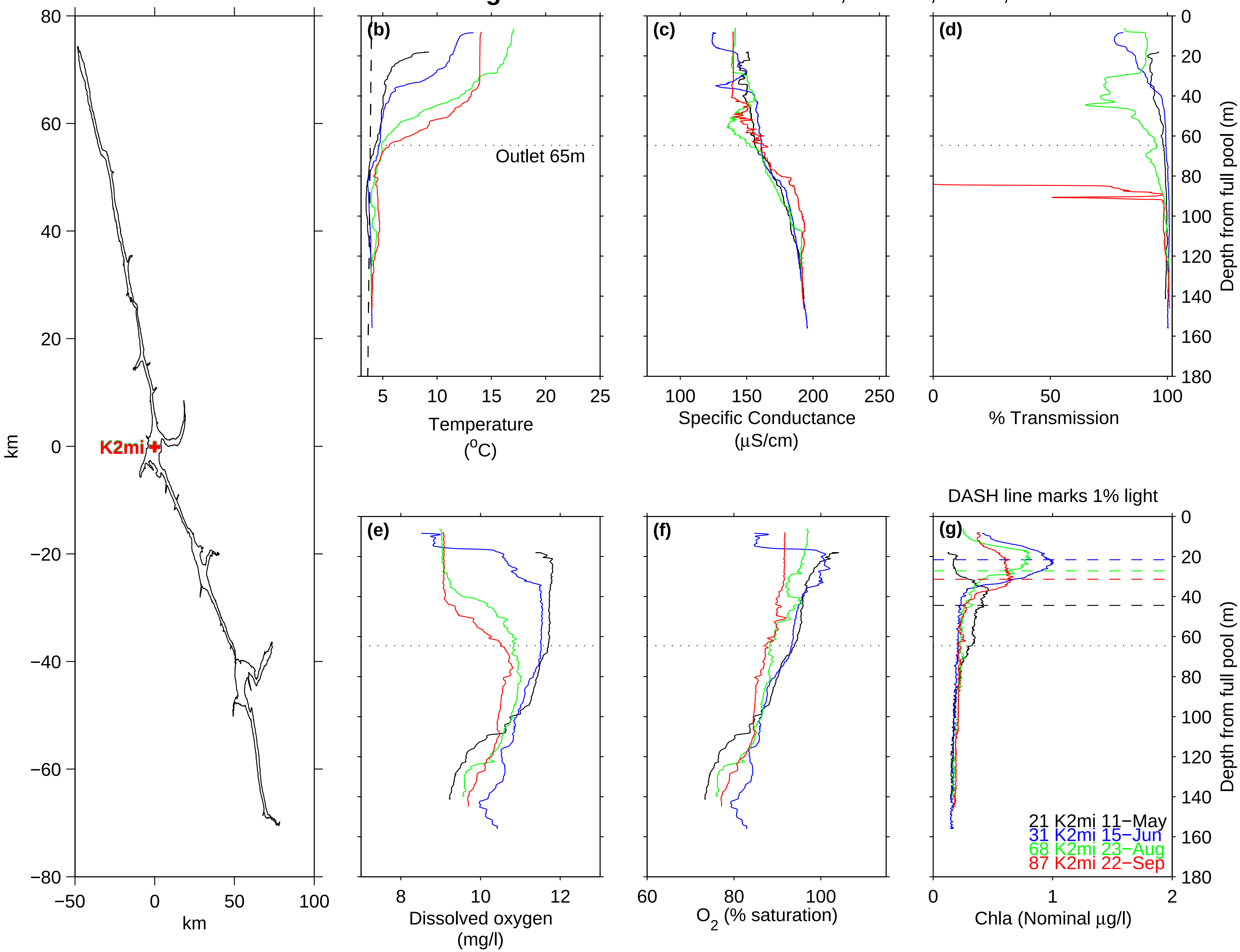


Figure B2.10 Kinbasket Reservoir, Columbia, K3co, 2015

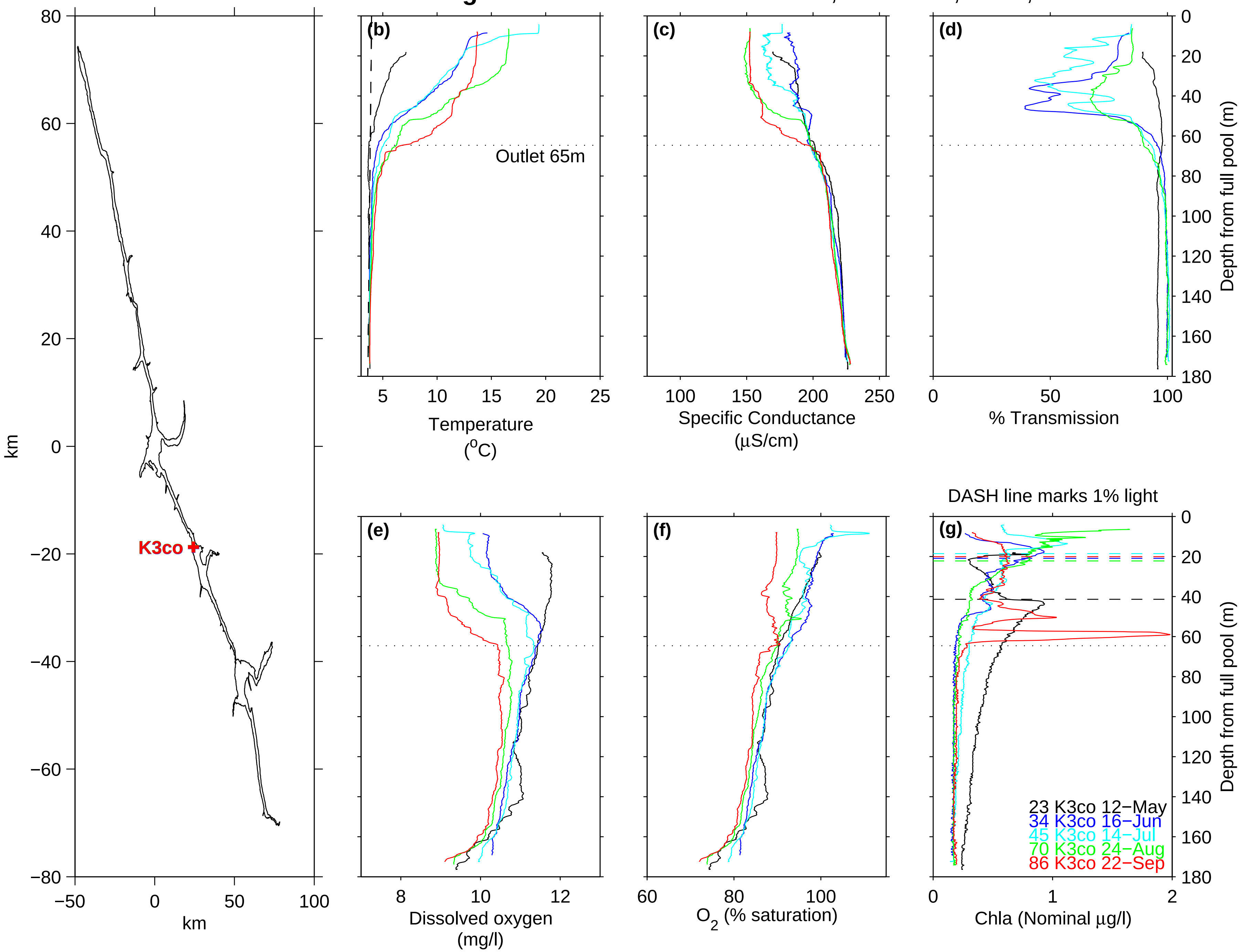


Figure B2.11 Kinbasket Reservoir, Canoe, Kca1, 2015

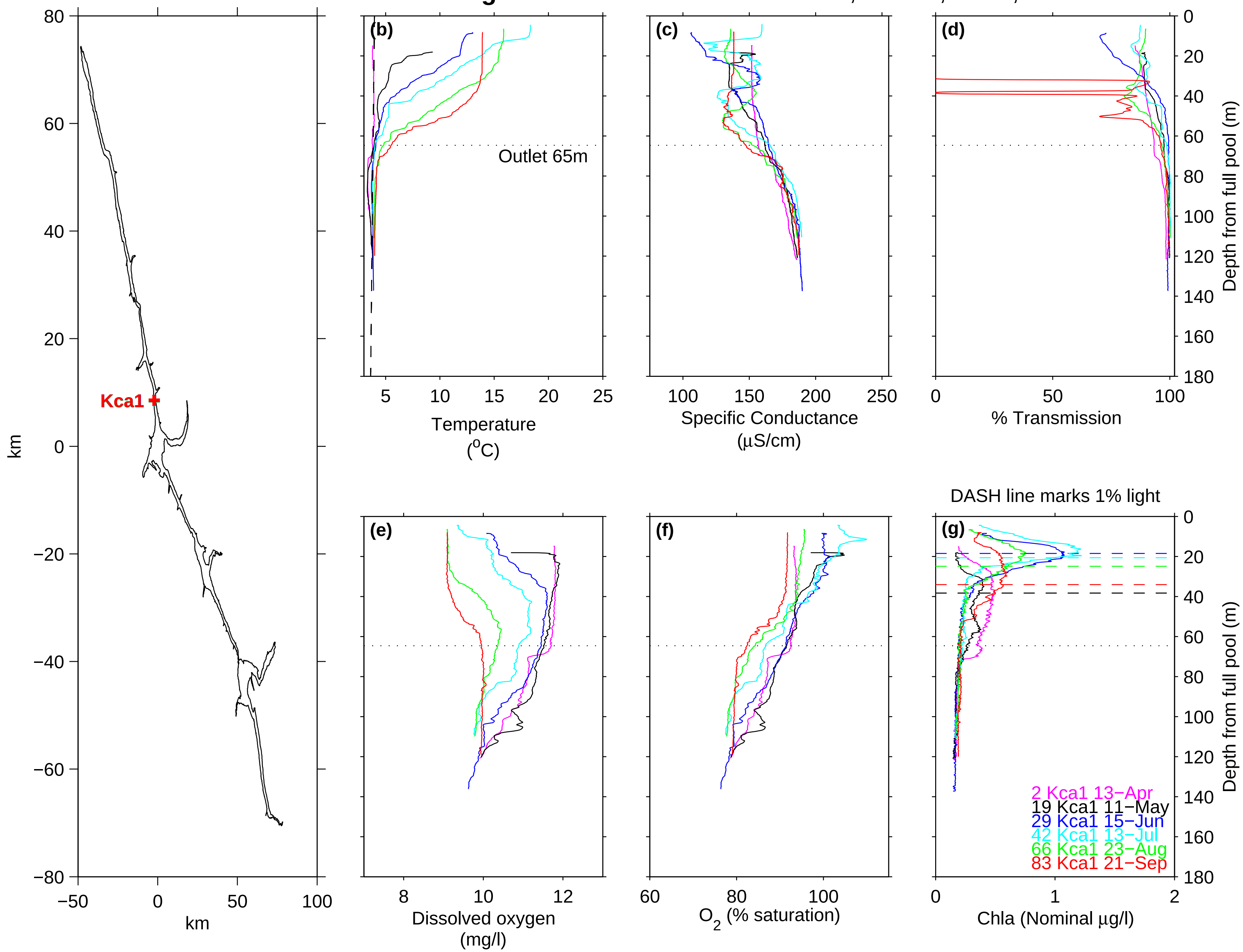


Figure B2.12 Kinbasket Reservoir, Wood, Kwo1, 2015

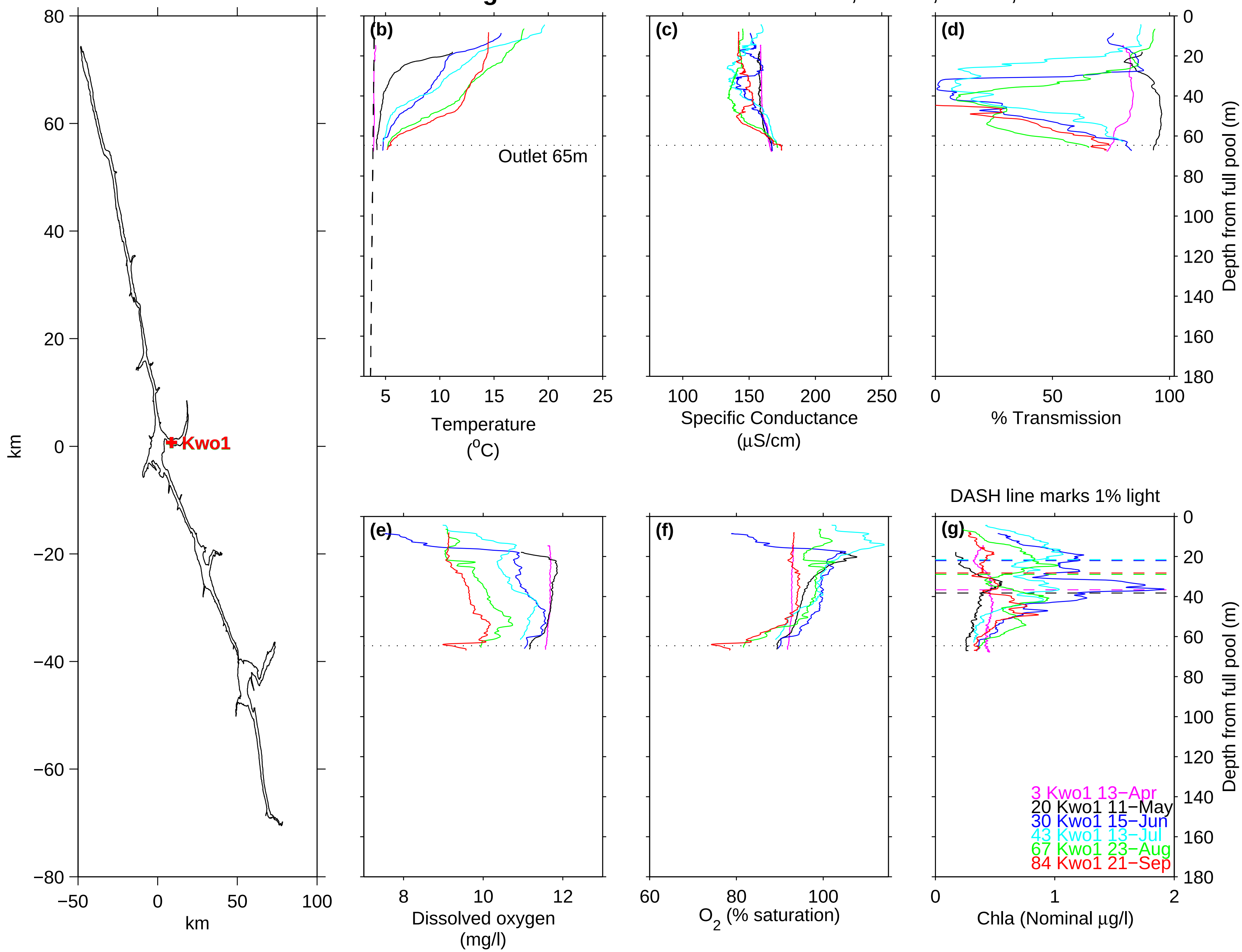


Figure C1.1 Kinbasket Reservoir 3 Jun, 2014

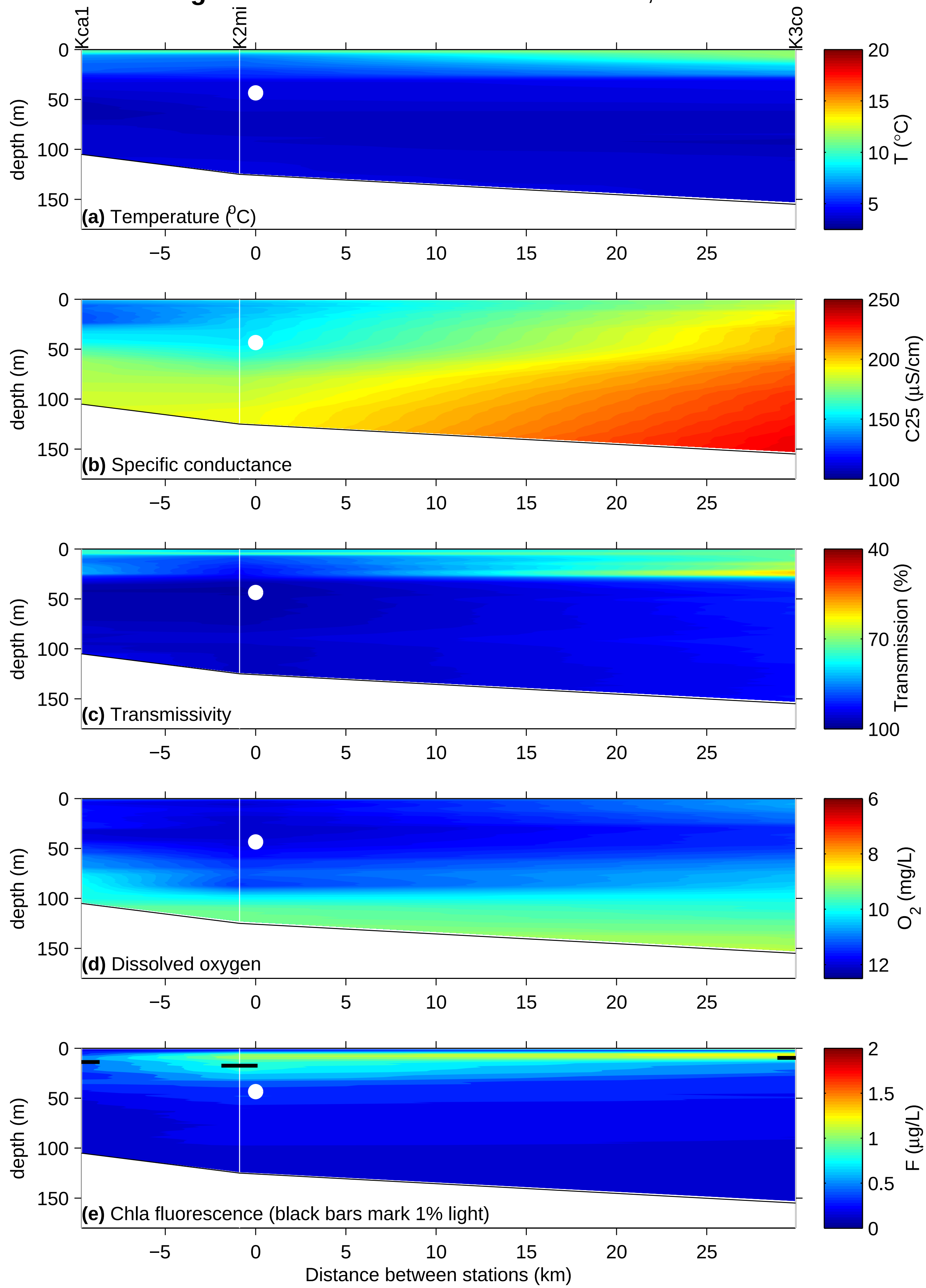


Figure C1.2 Kinbasket Reservoir 16−17 Jun, 2014

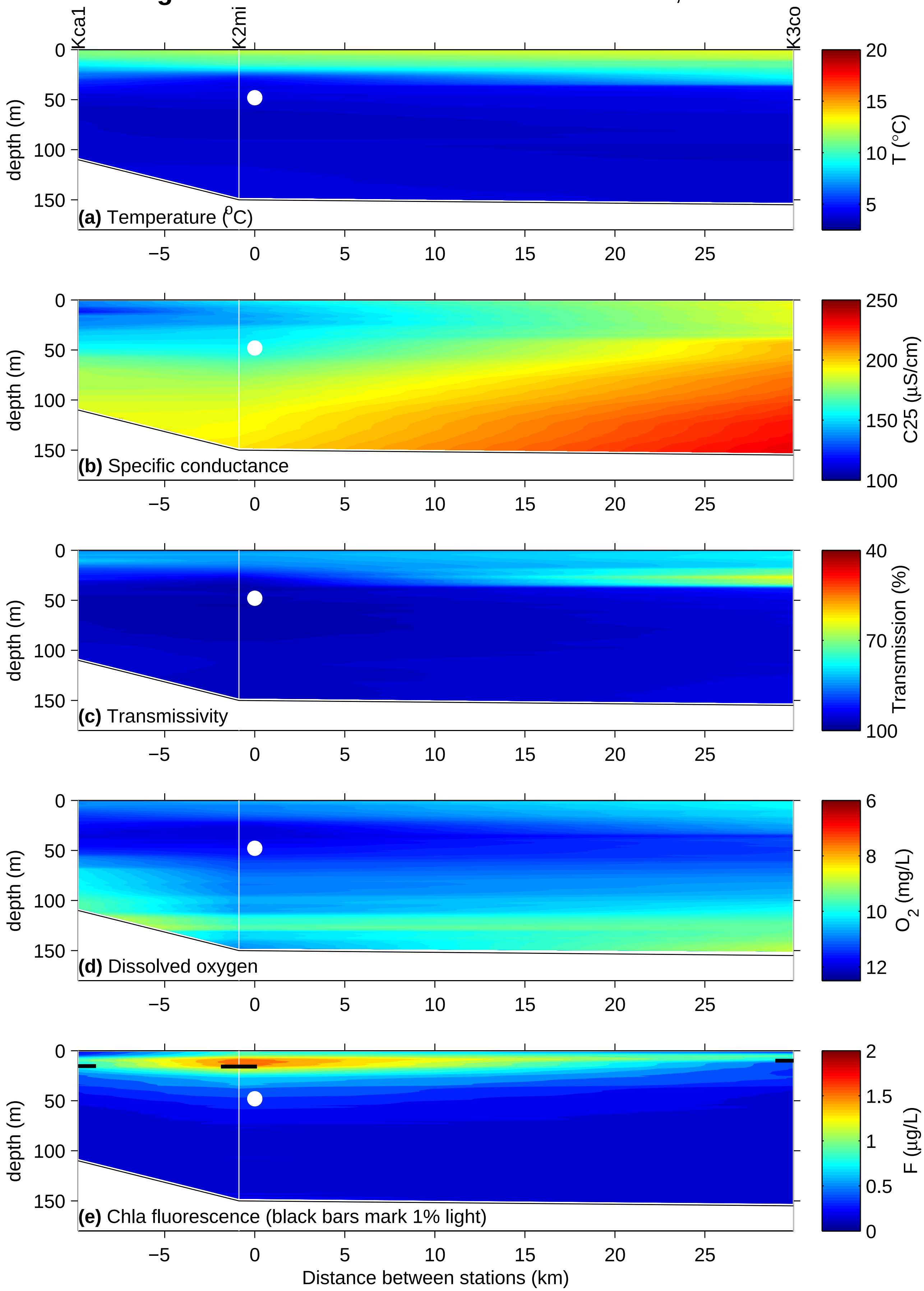


Figure C1.3 Kinbasket Reservoir 14−15 Jul, 2014

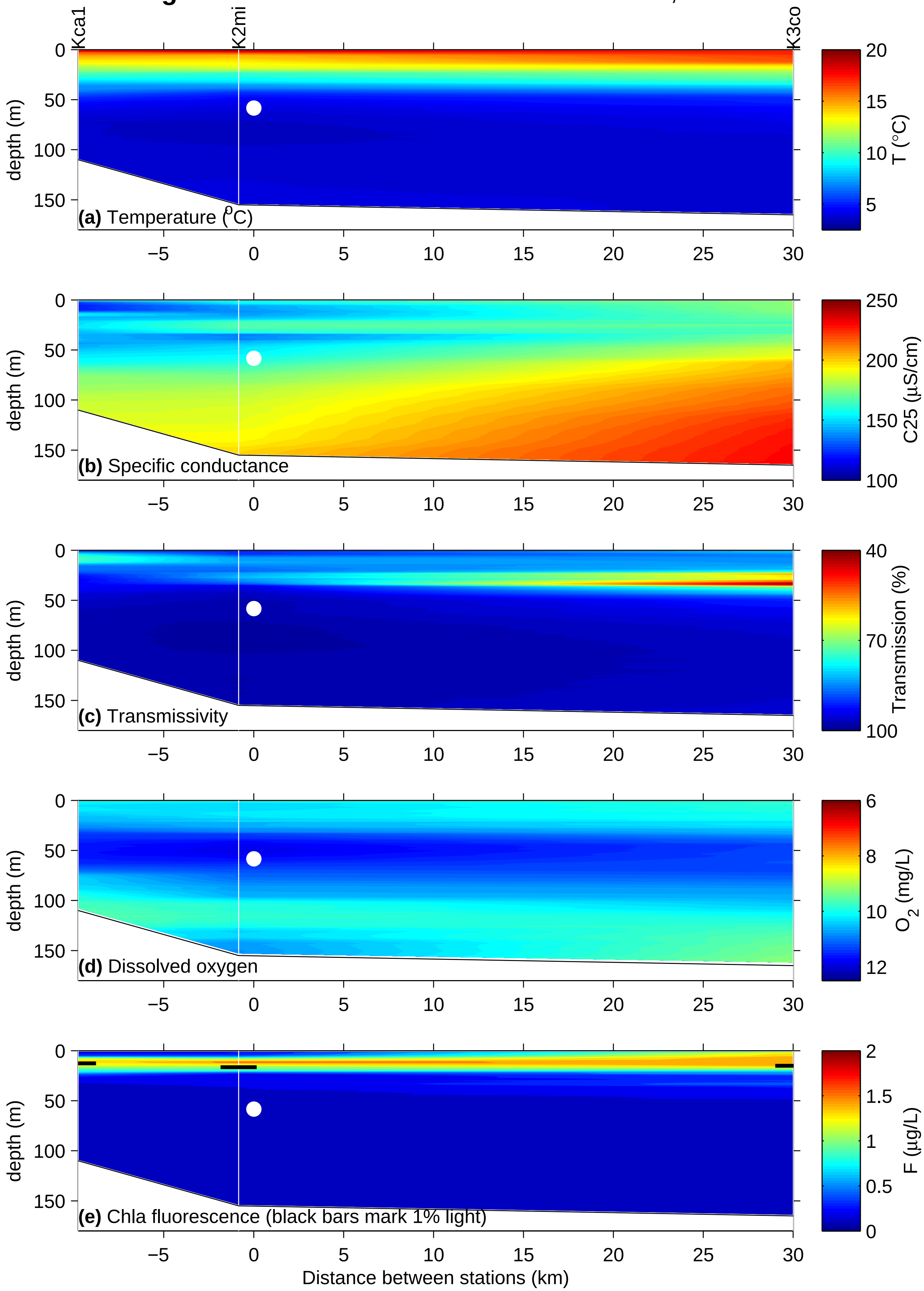


Figure C1.4 Kinbasket Reservoir 11−12 Aug, 2014

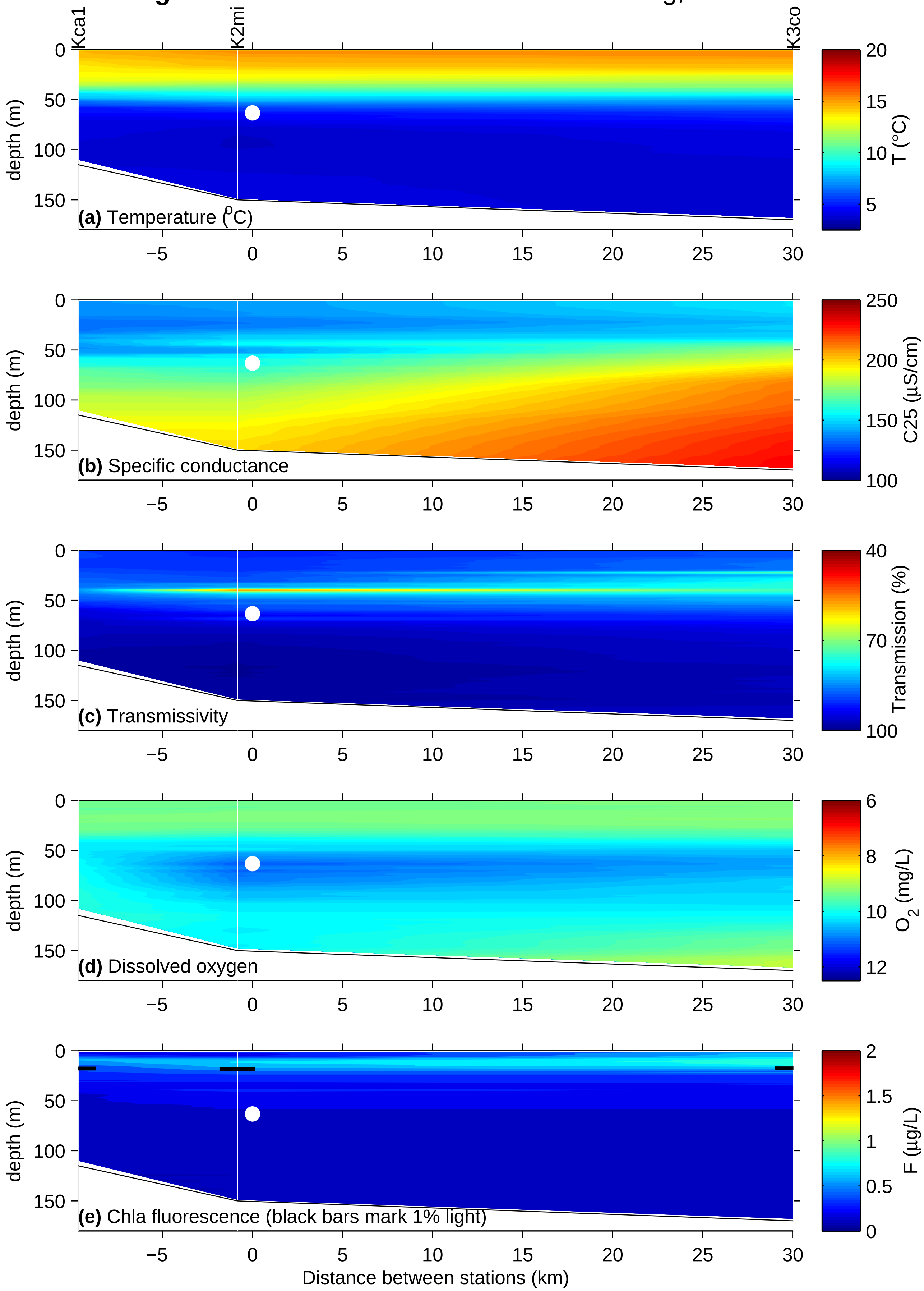


Figure C1.5 Kinbasket Reservoir 15−16 Sep, 2014

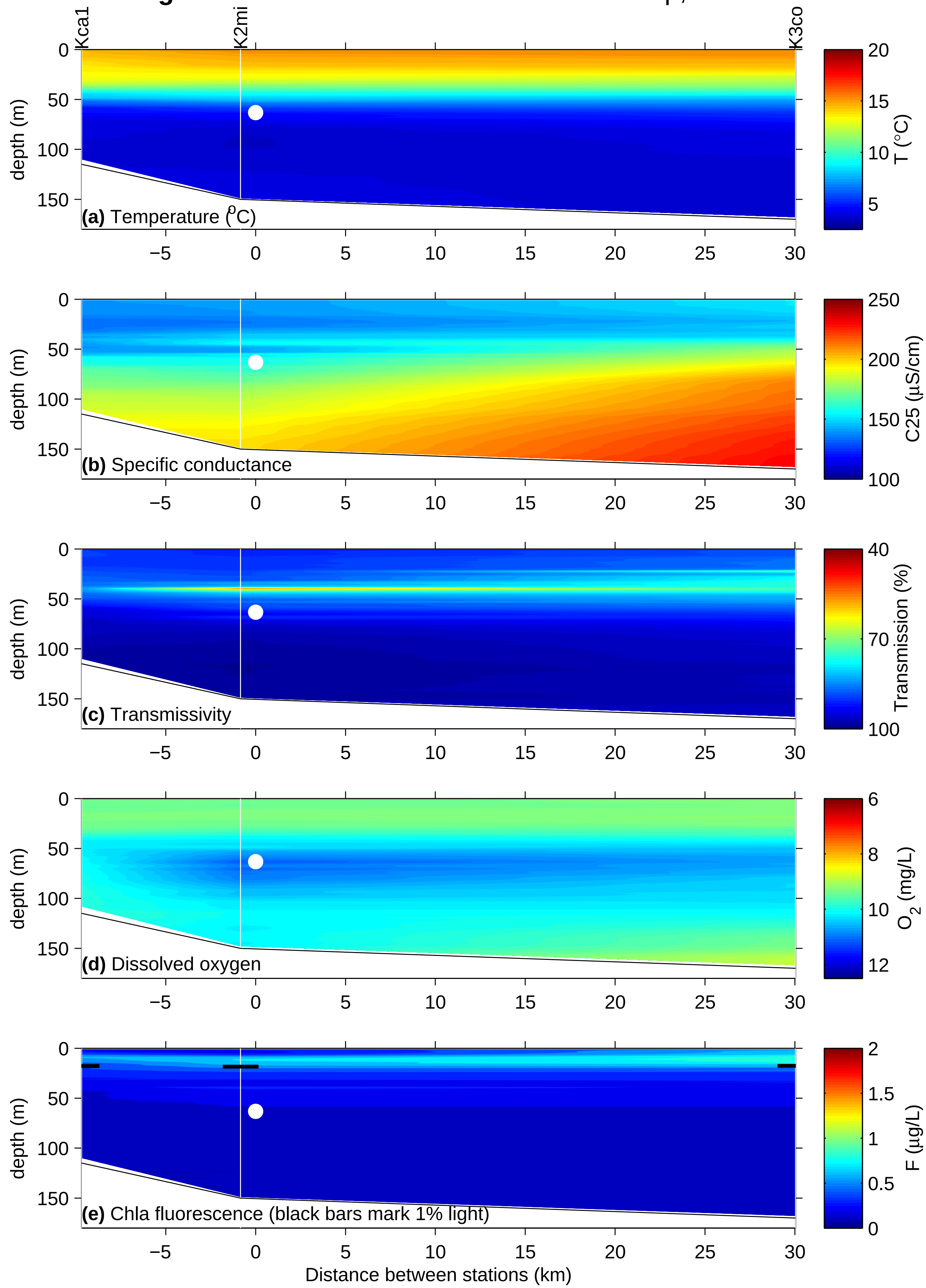


Figure C2.1 Kinbasket Reservoir 11−12 May 2015

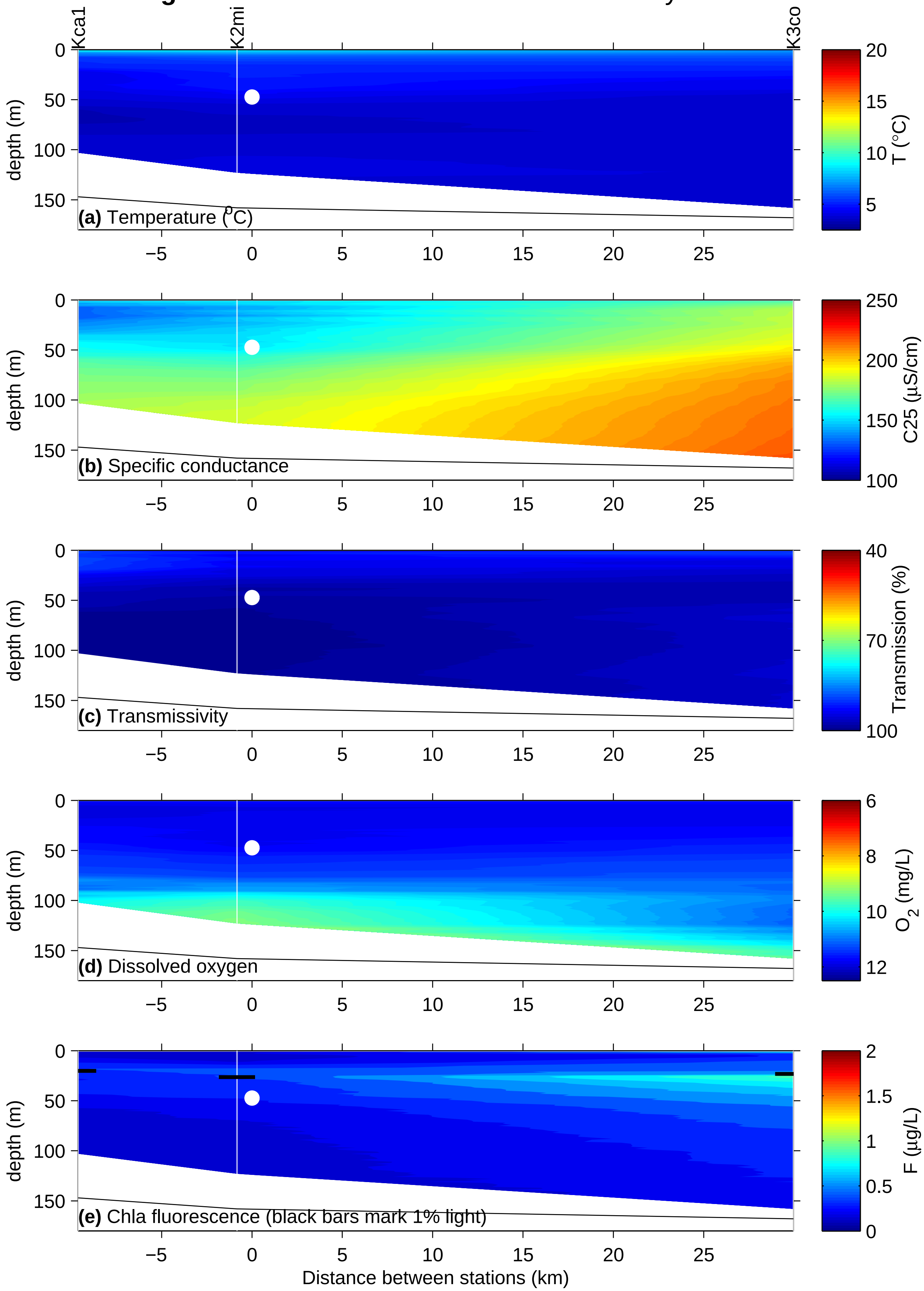


Figure C2.2 Kinbasket Reservoir 15−16 Jun 2015

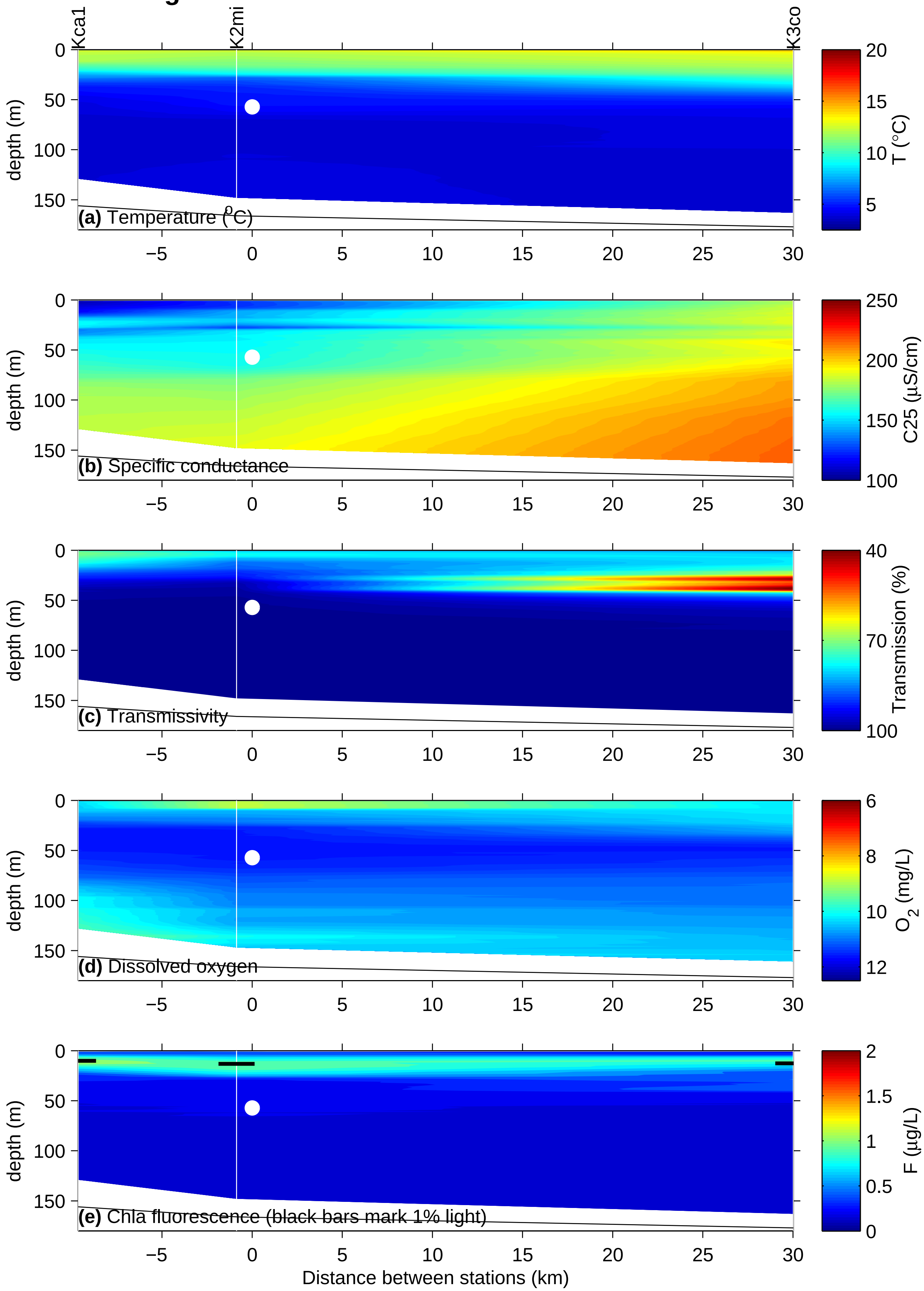


Figure C2.3 Kinbasket Reservoir 13−14 Jul 2015

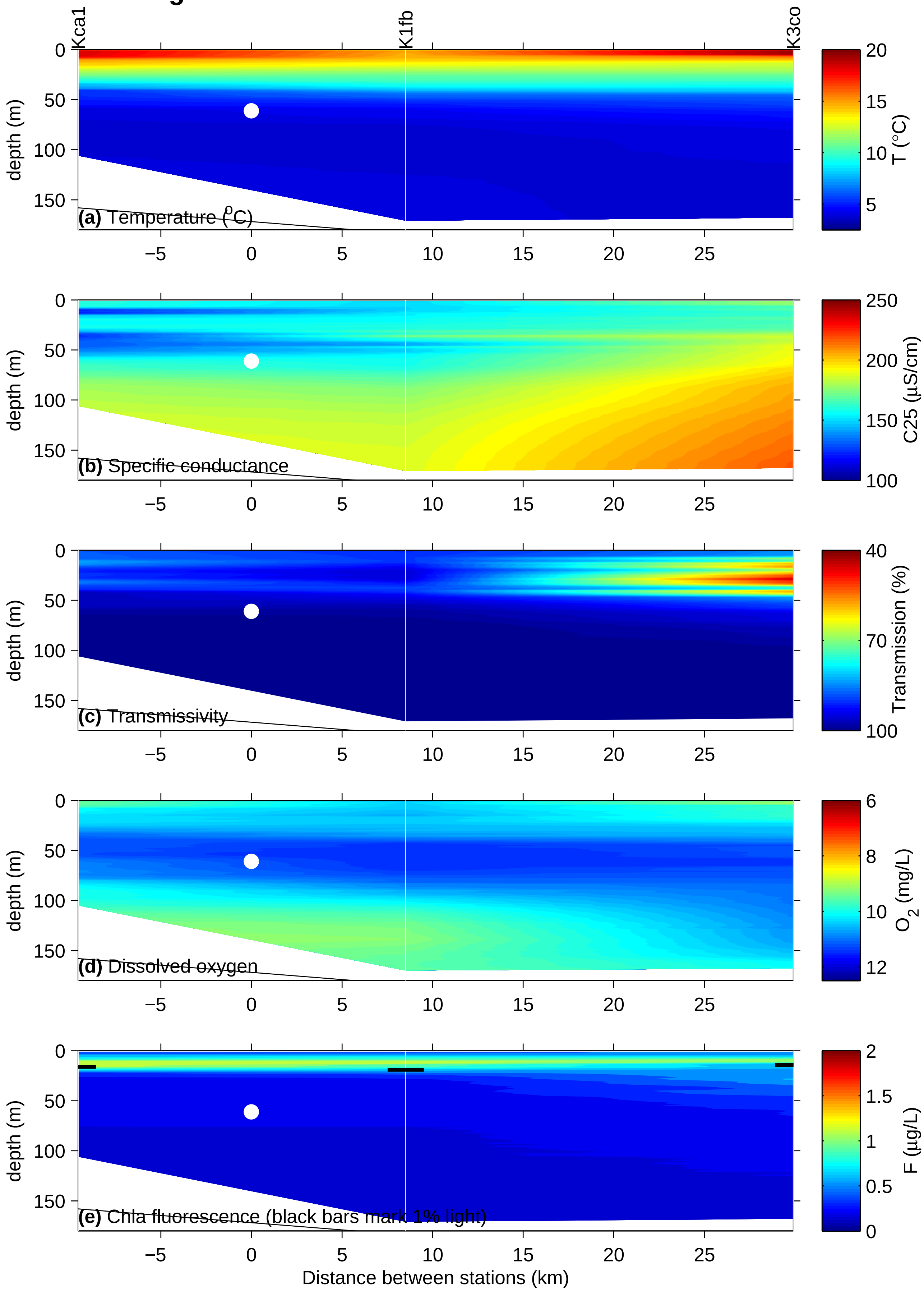


Figure C2.4 Kinbasket Reservoir 23−24 Aug 2015

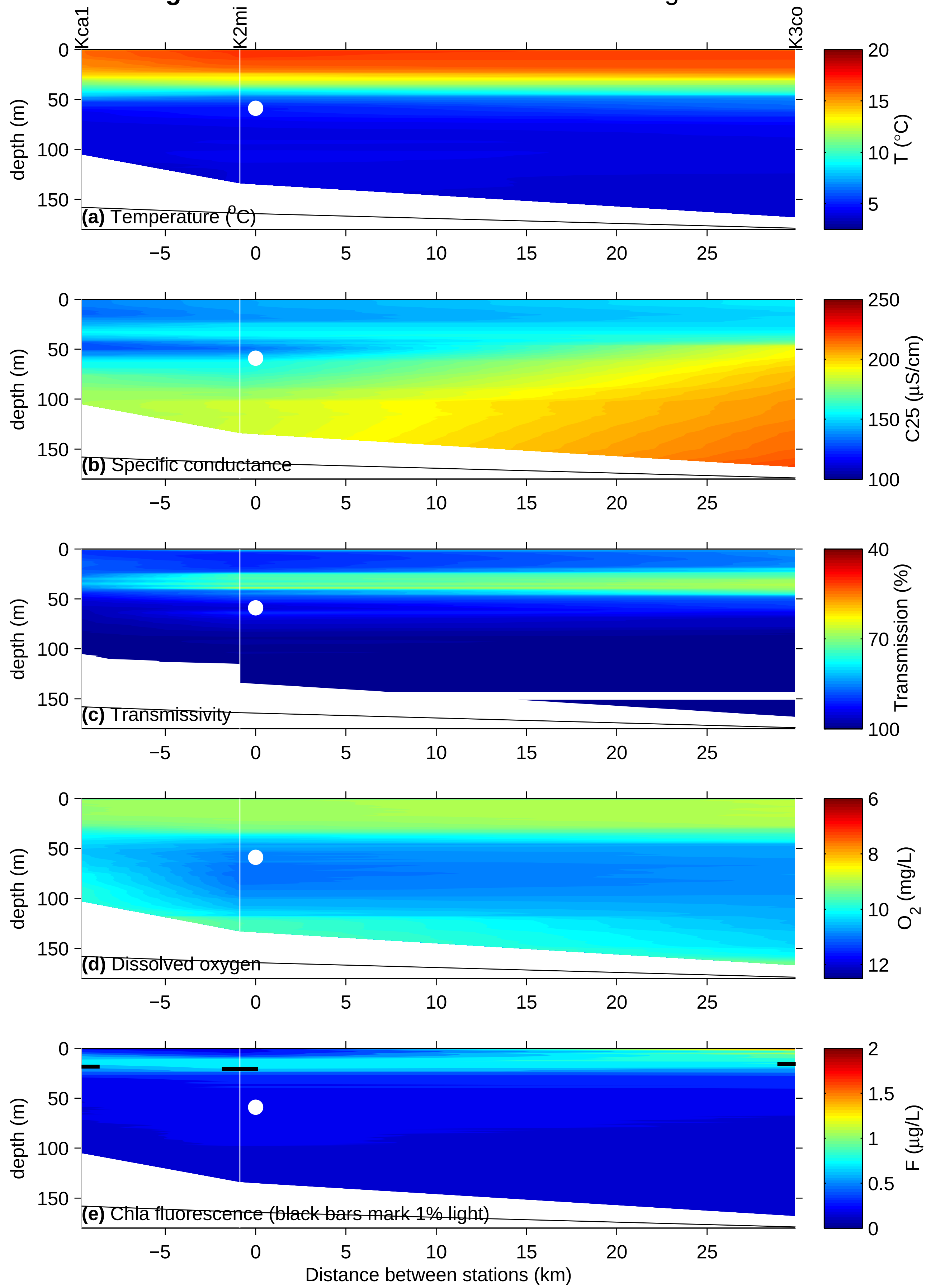


Figure C2.5 Kinbasket Reservoir 21−22 Sep 2015

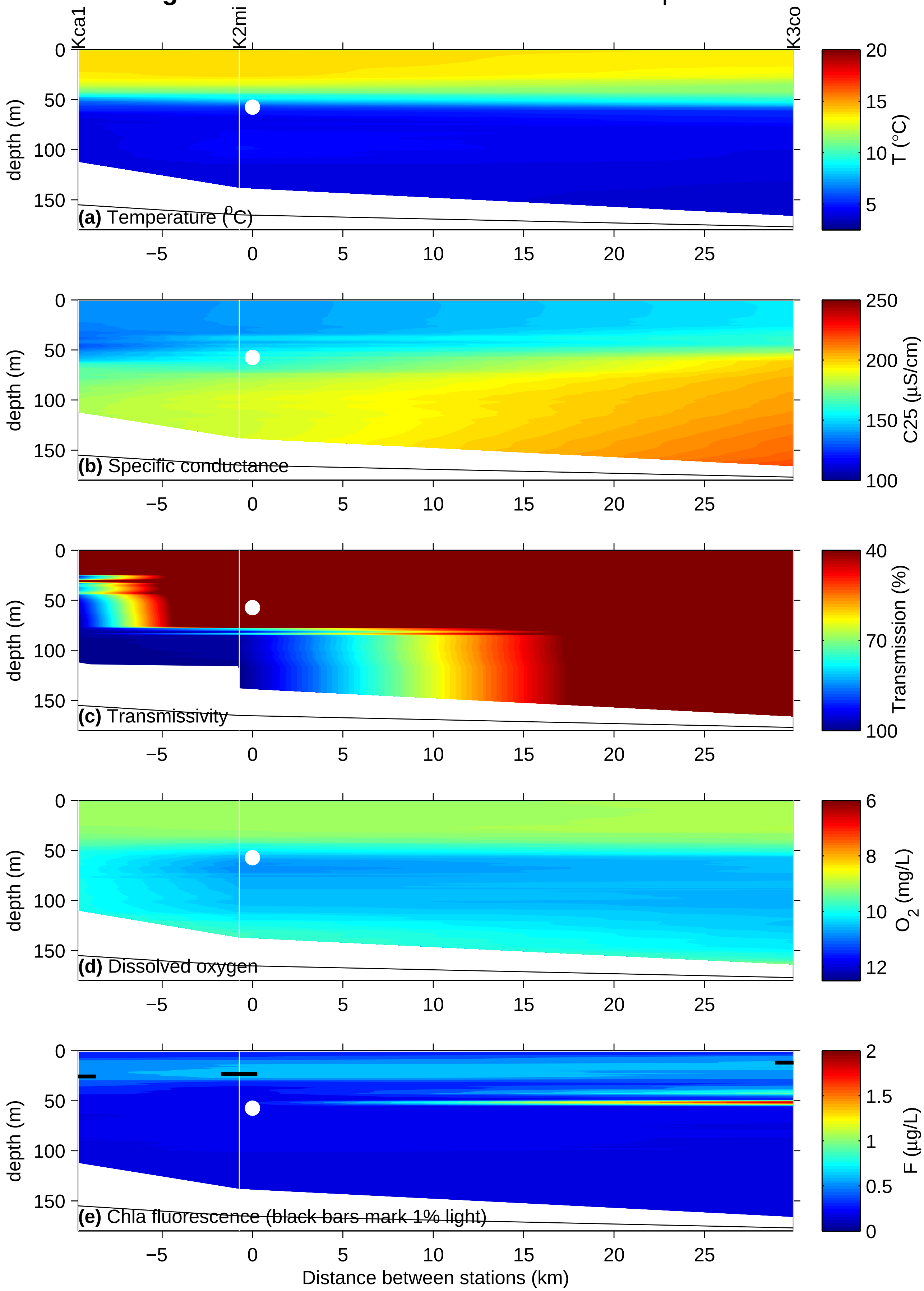


Figure D1.1 Revelstoke Reservoir, 21 May 2014

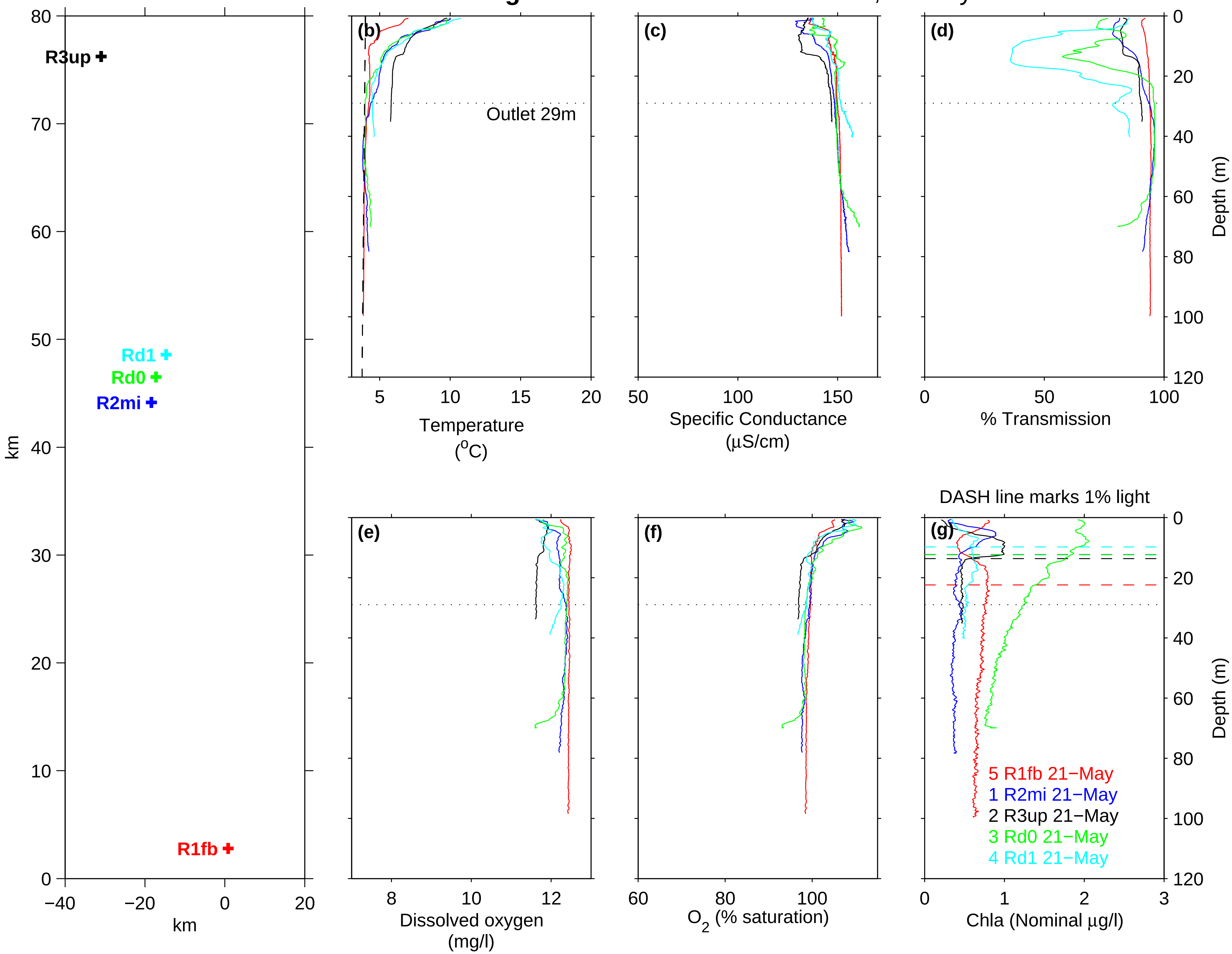
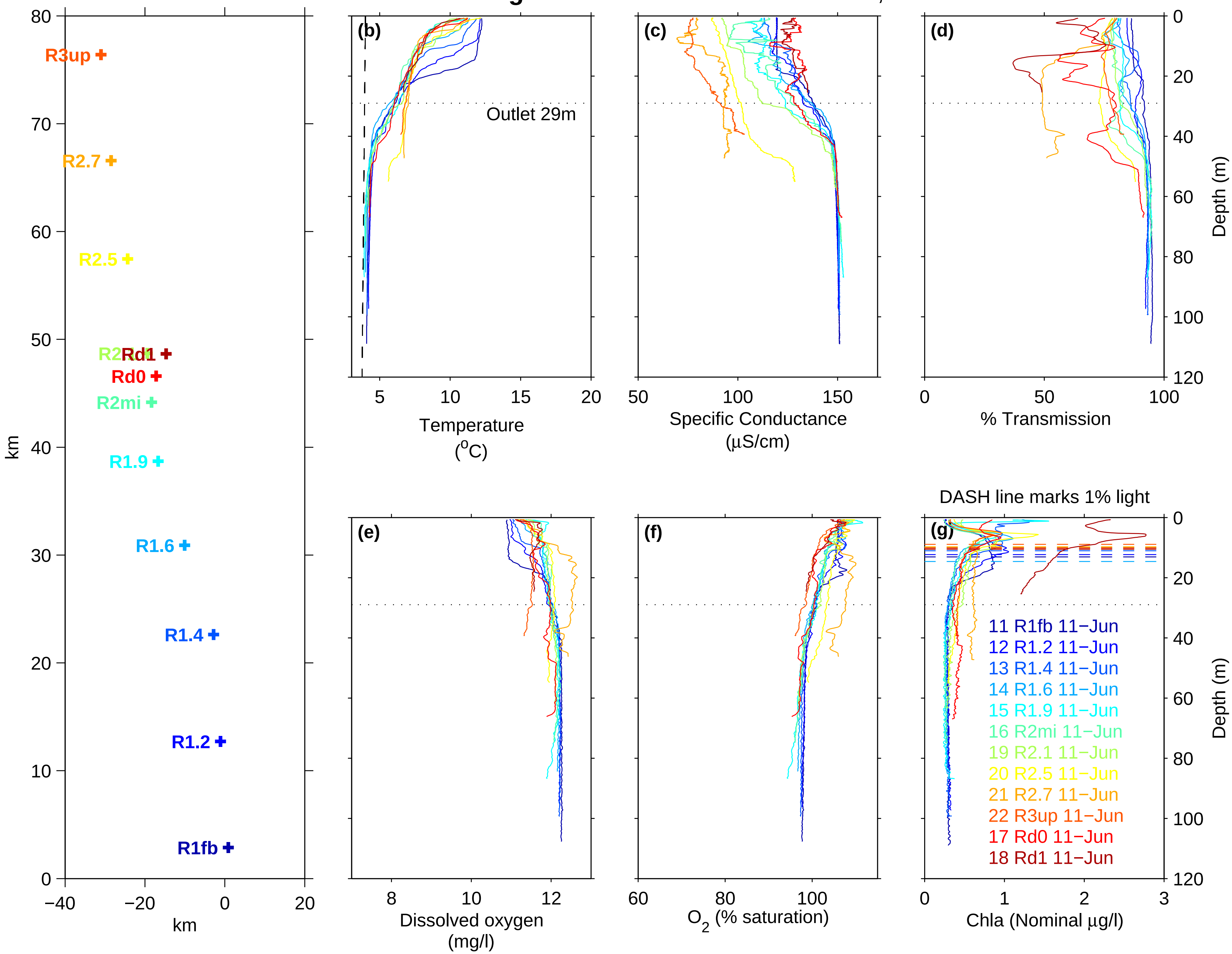


Figure D1.2 Revelstoke Reservoir, 11 Jun 2014



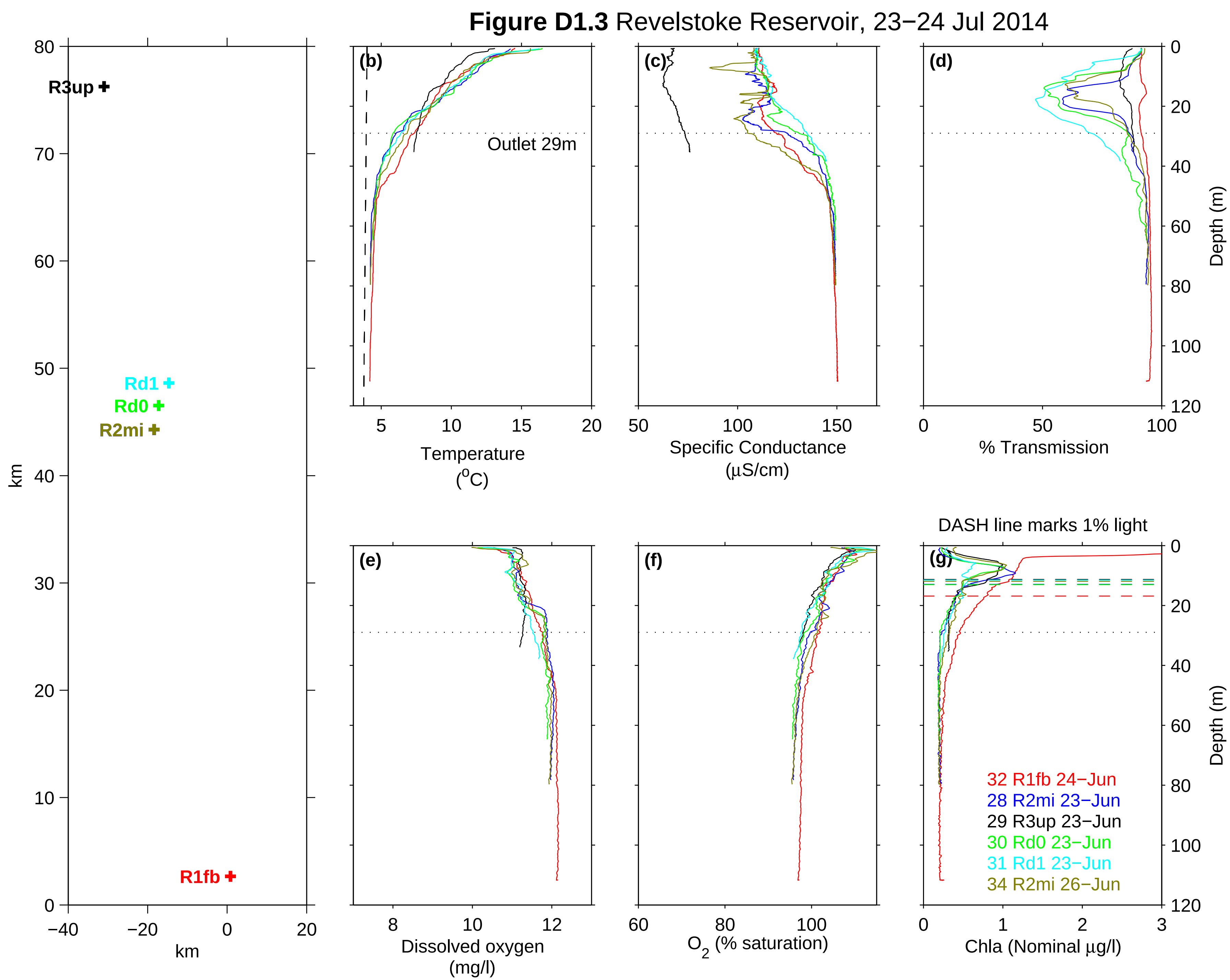


Figure D1.3 Revelstoke Reservoir, 23−24 Jul 2014
R3up
Rd1
Rd0
R2mi
R1fb
km
(b)
Outlet 29m
Temperature (°C)
(c)
Specific Conductance (µS/cm)
(d)
% Transmission
Depth (m)
DASH line marks 1% light
(e)
Dissolved oxygen (mg/l)
(f)
O2 (% saturation)
(g)
Chla (Nominal µg/l)
32 R1fb 24−Jun
28 R2mi 23−Jun
29 R3up 23−Jun
30 Rd0 23−Jun
31 Rd1 23−Jun
34 R2mi 26−Jun

Figure D1.4 Revelstoke Reservoir, 21 Jul 2014

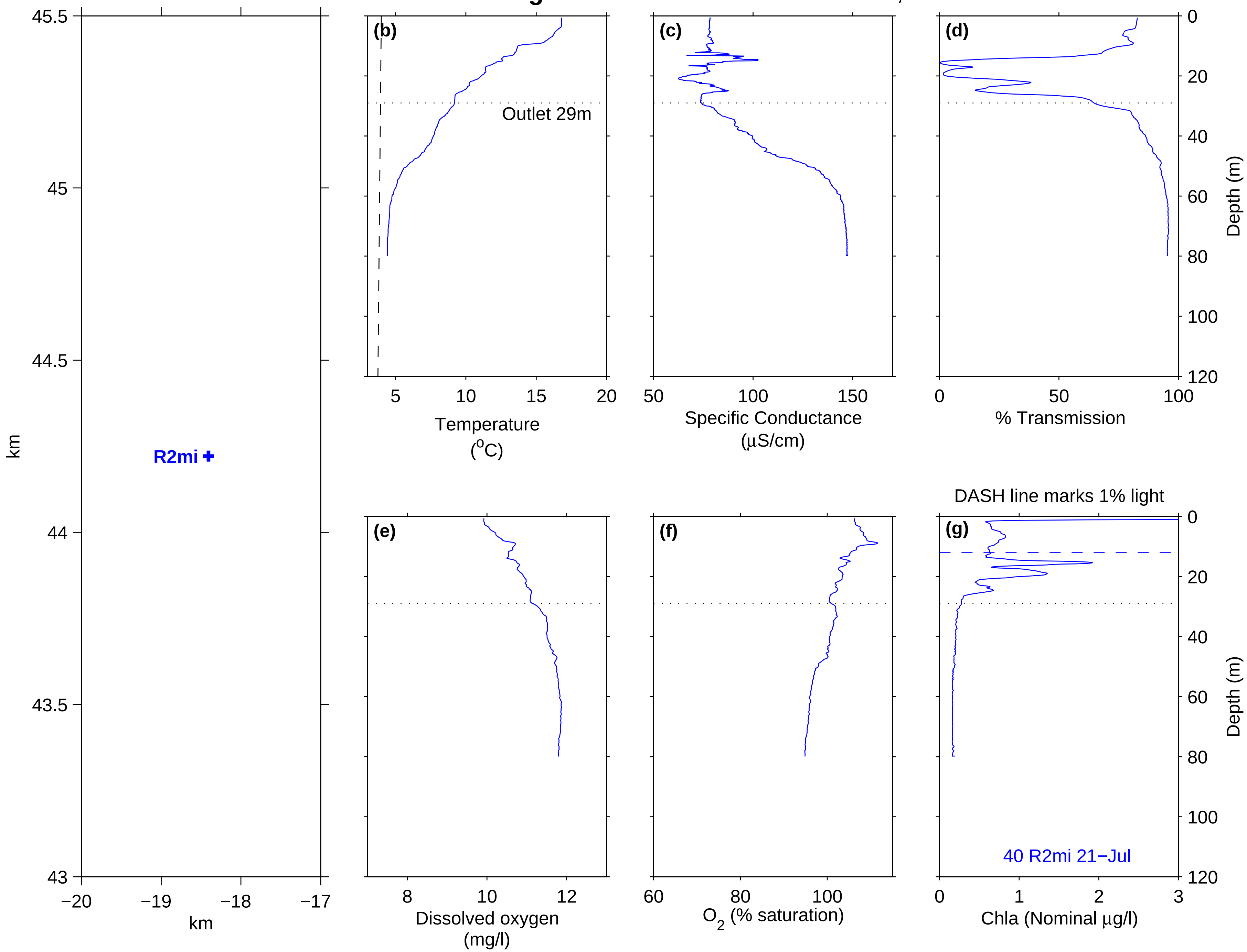


Figure D1.5 Revelstoke Reservoir, 18−19 Aug 2014

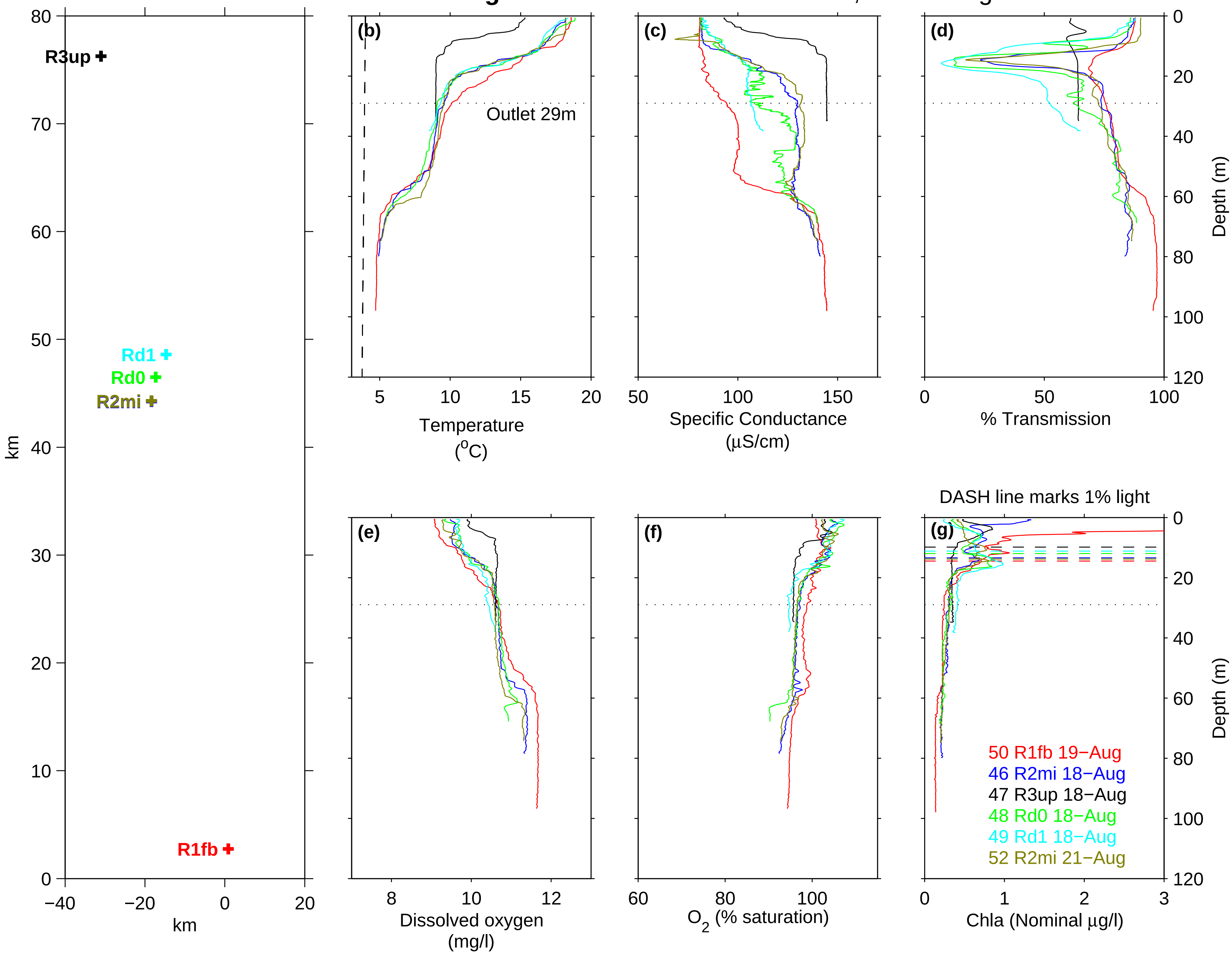


Figure D1.6 Revelstoke Reservoir, 22−23 Sep 2014

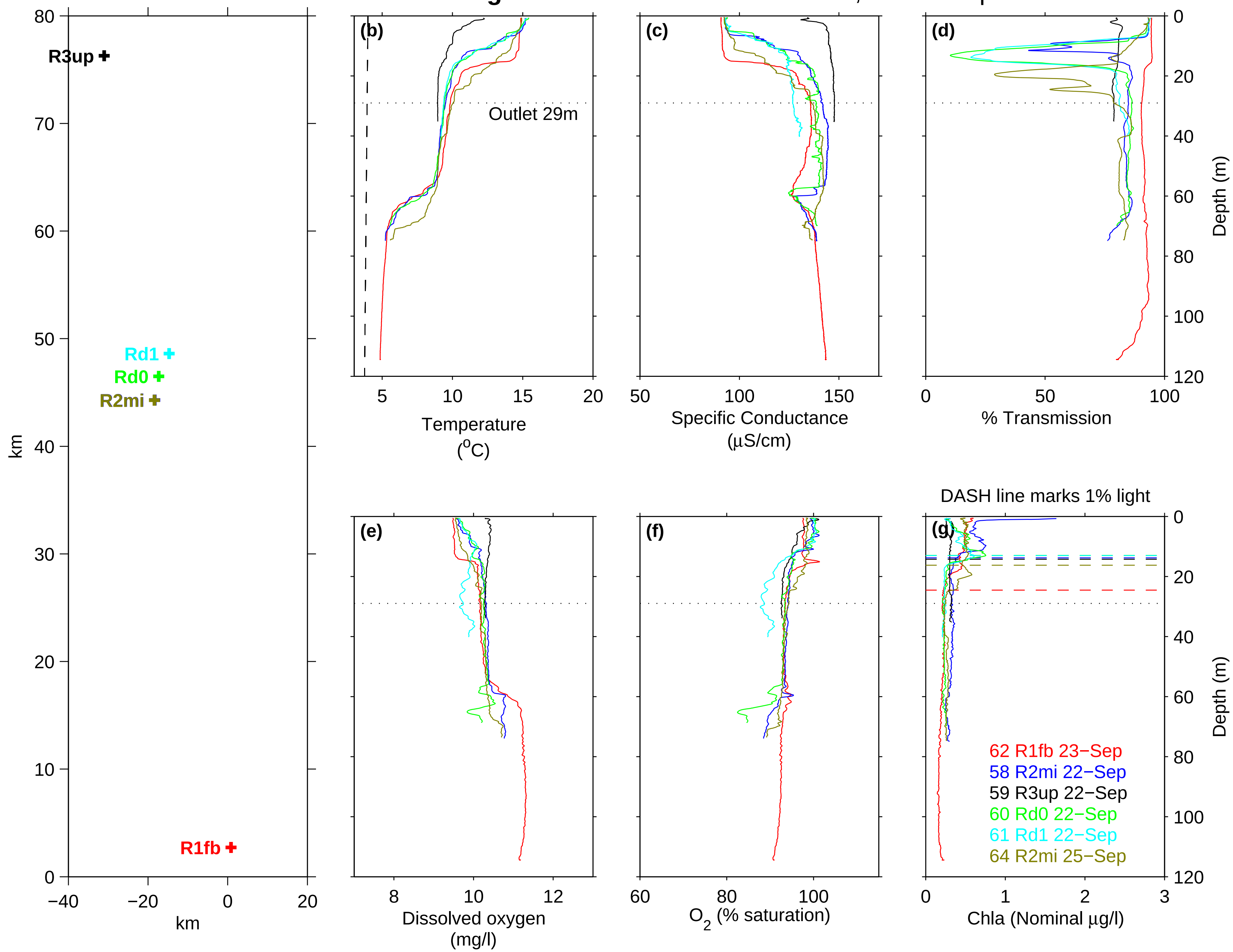


Figure D1.7 Revelstoke Reservoir, 14−15 Oct 2014

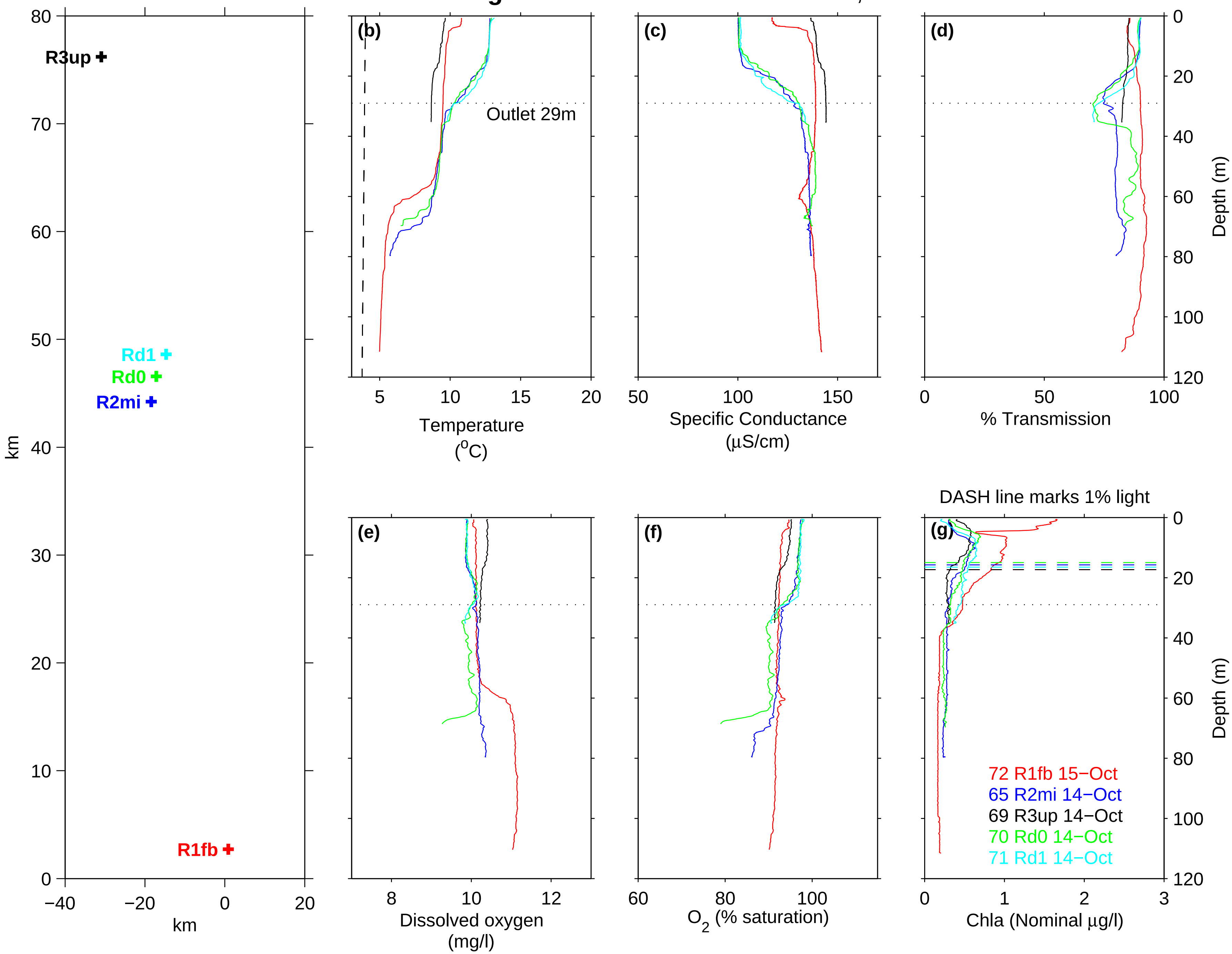


Figure D1.8 Revelstoke Reservoir, Forebay 2014

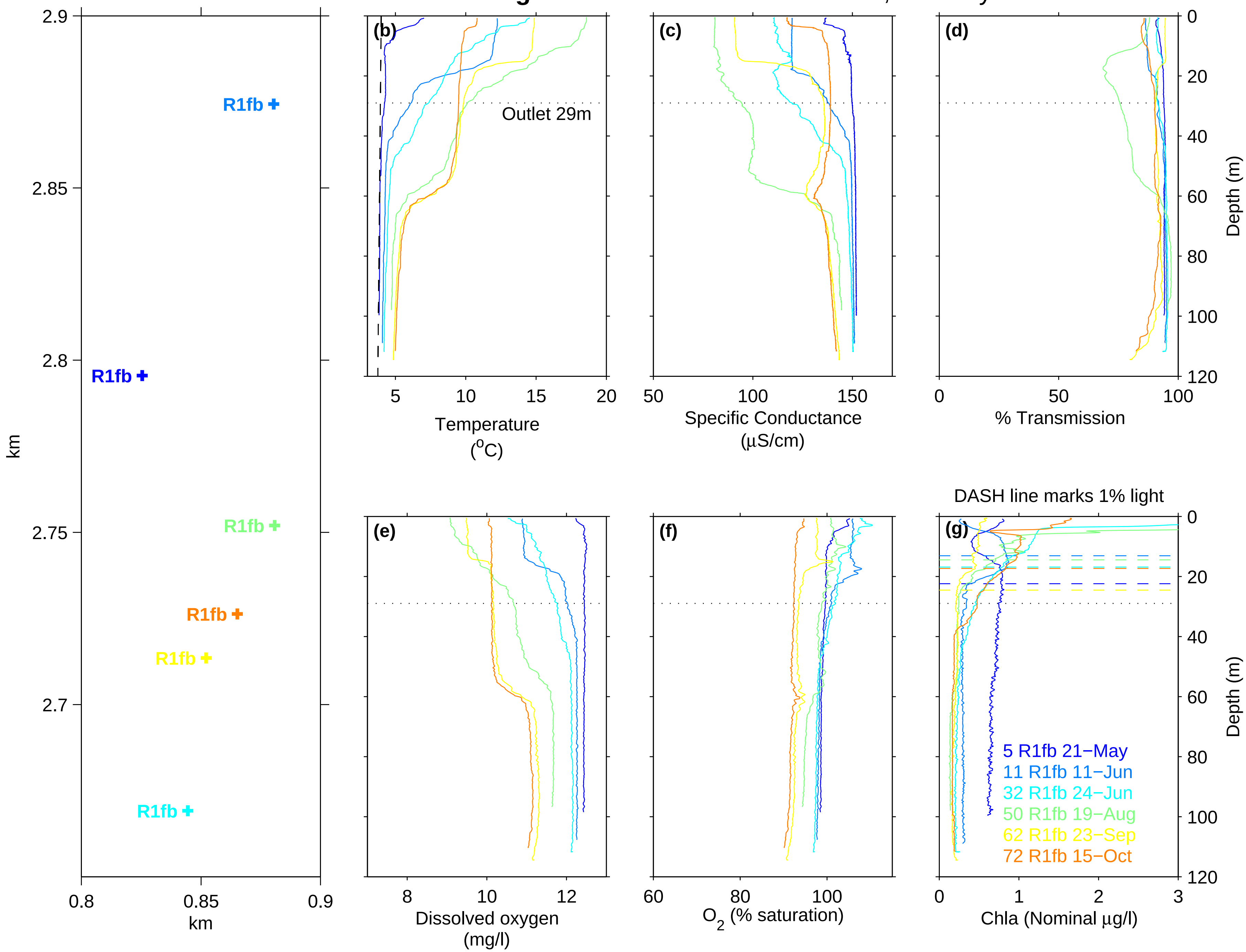


Figure D1.9 Revelstoke Reservoir, Middle 2014

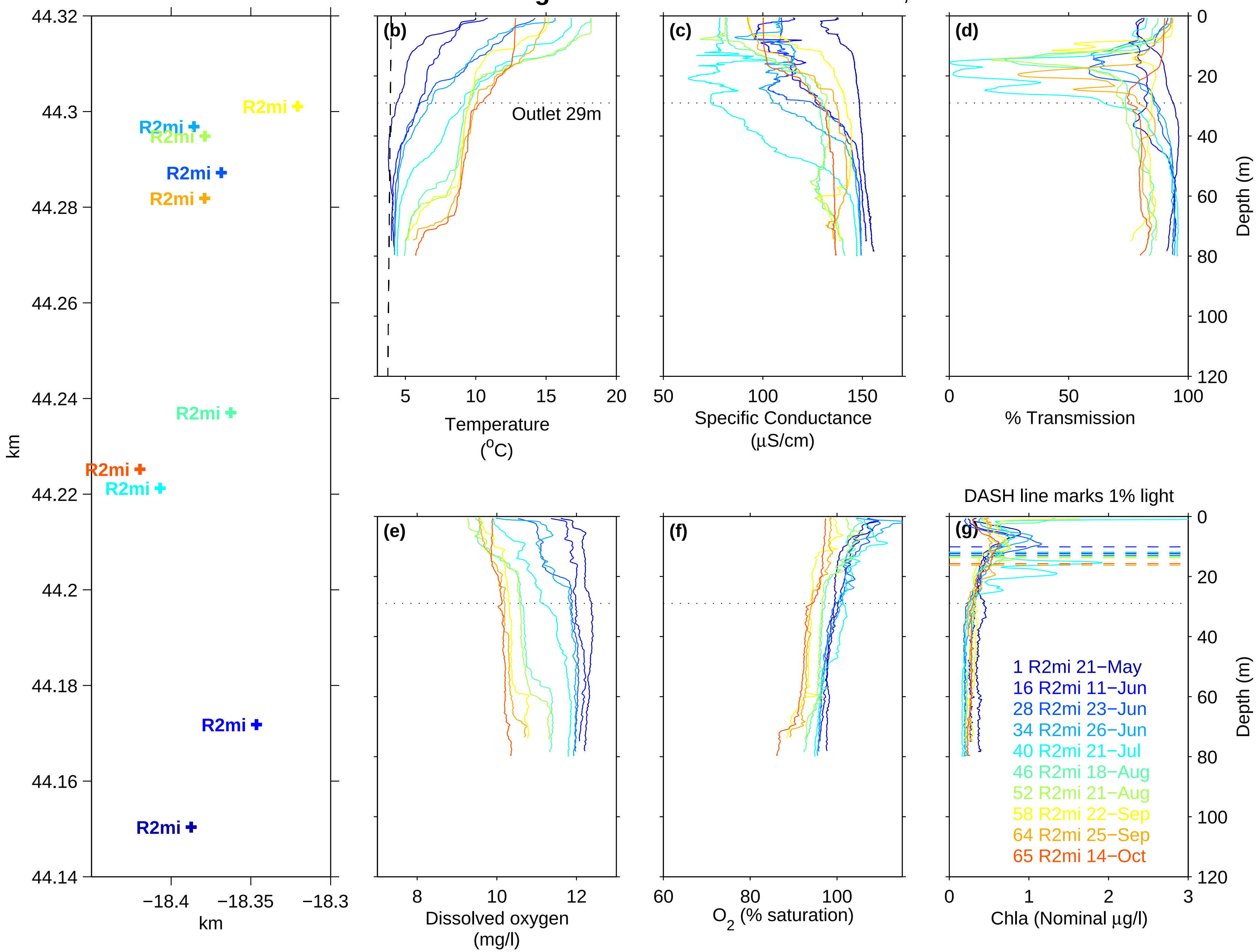


Figure D1.10 Revelstoke Reservoir, Upper 2014

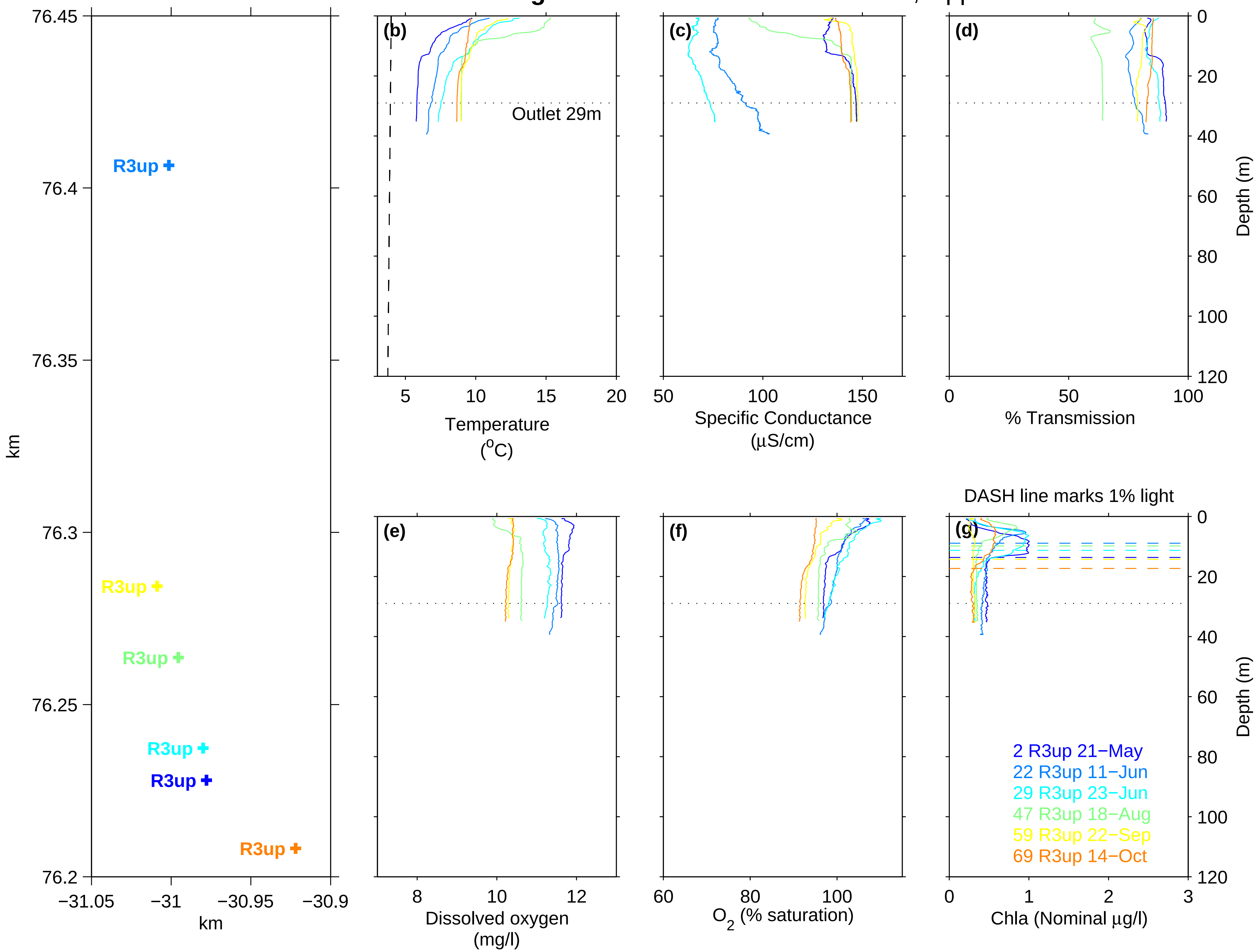


Figure D1.11 Revelstoke Reservoir, Downie Arm 2014

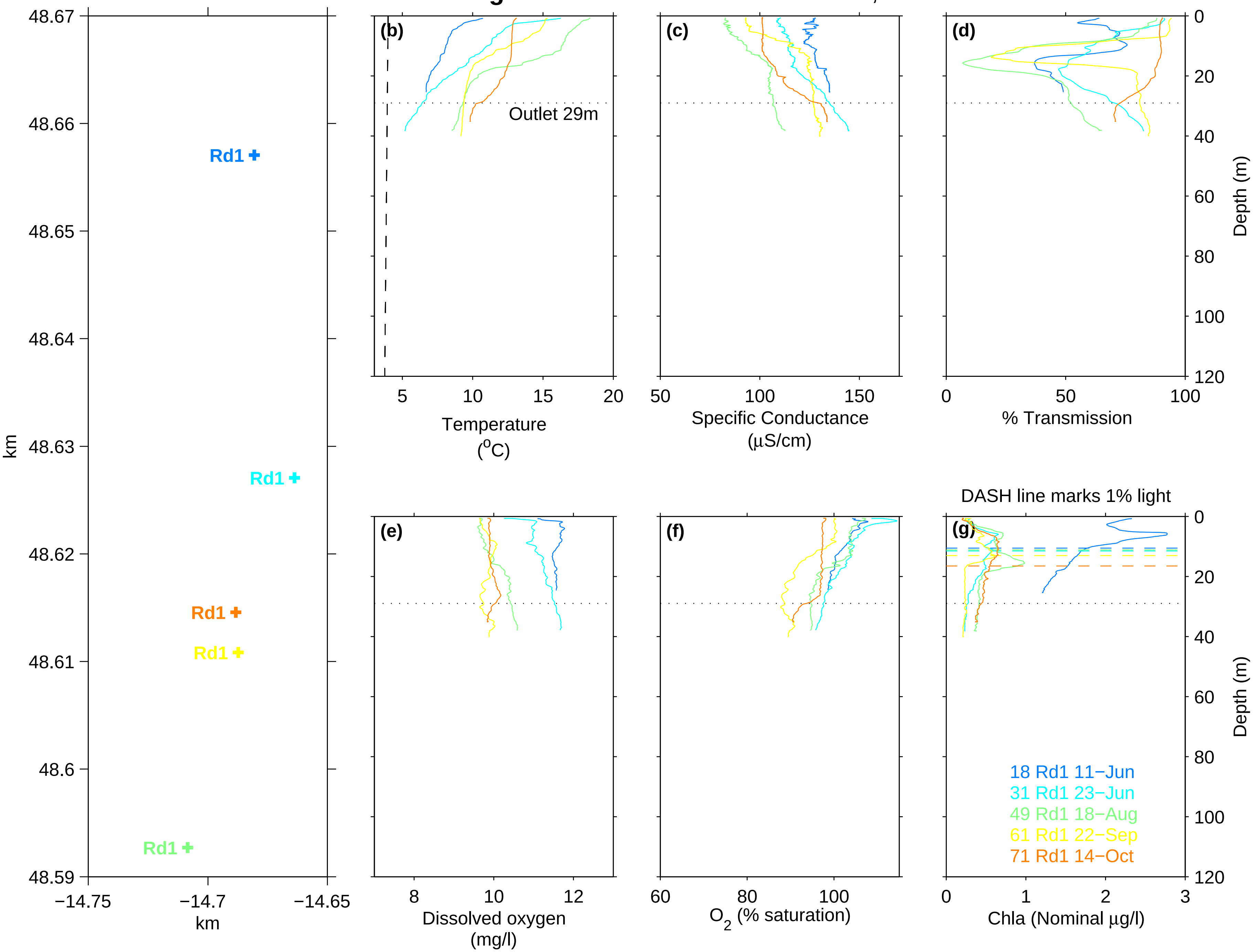


Figure D2.1 Revelstoke Reservoir, near forebay, 9−27 Apr 2015

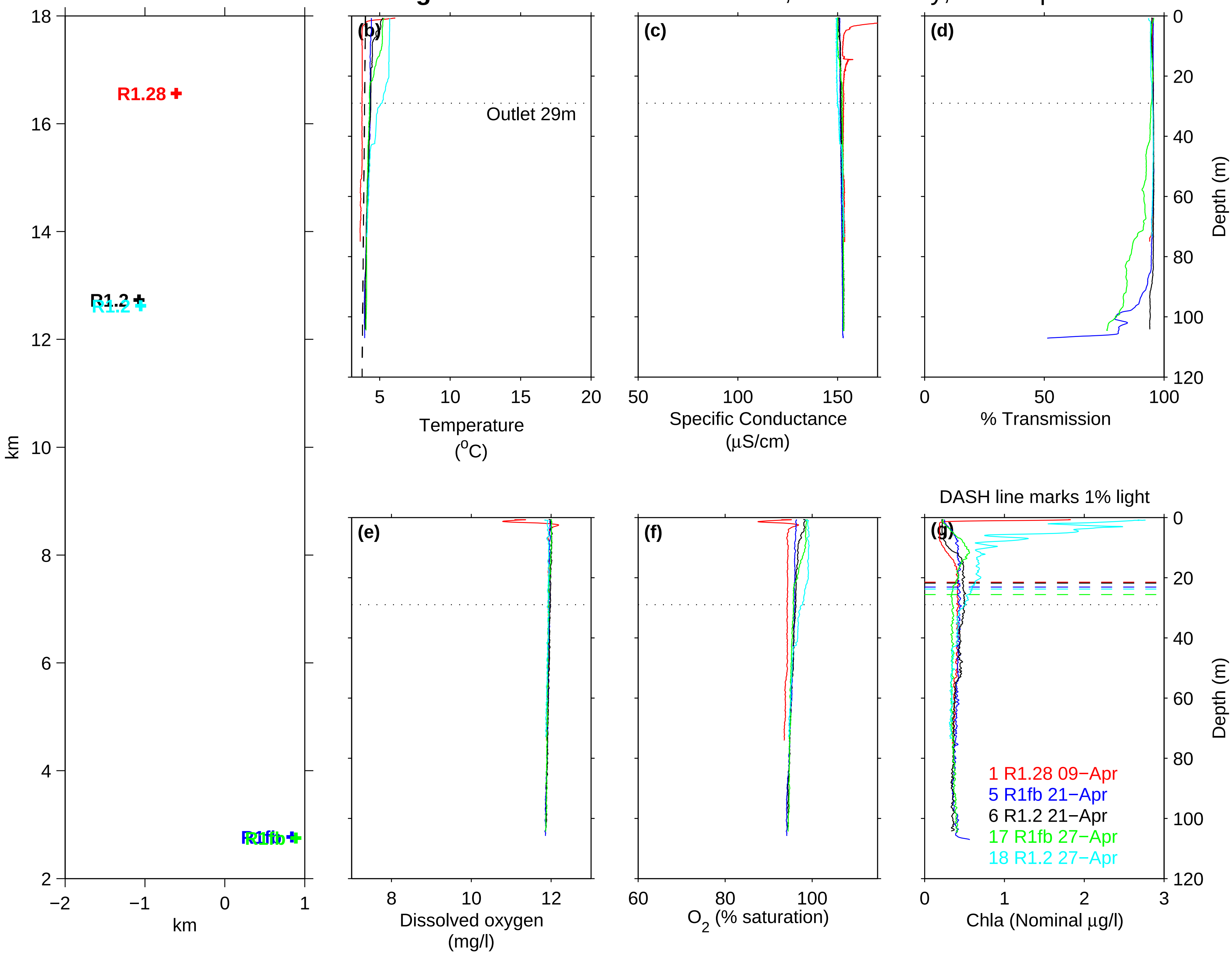


Figure D2.2 Revelstoke Reservoir, 21 Apr 2015

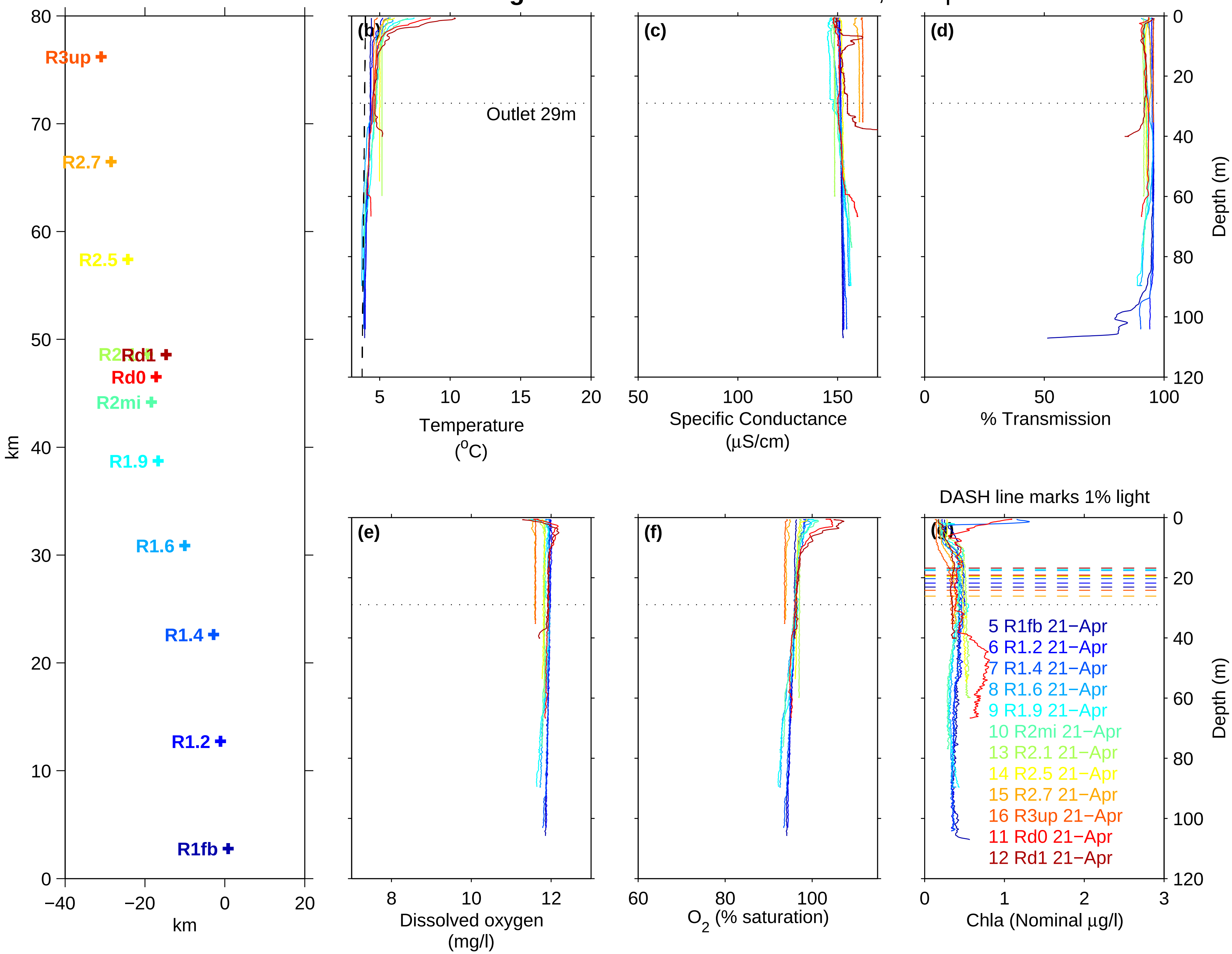


Figure D2.3 Revelstoke Reservoir, 19−20 May 2015

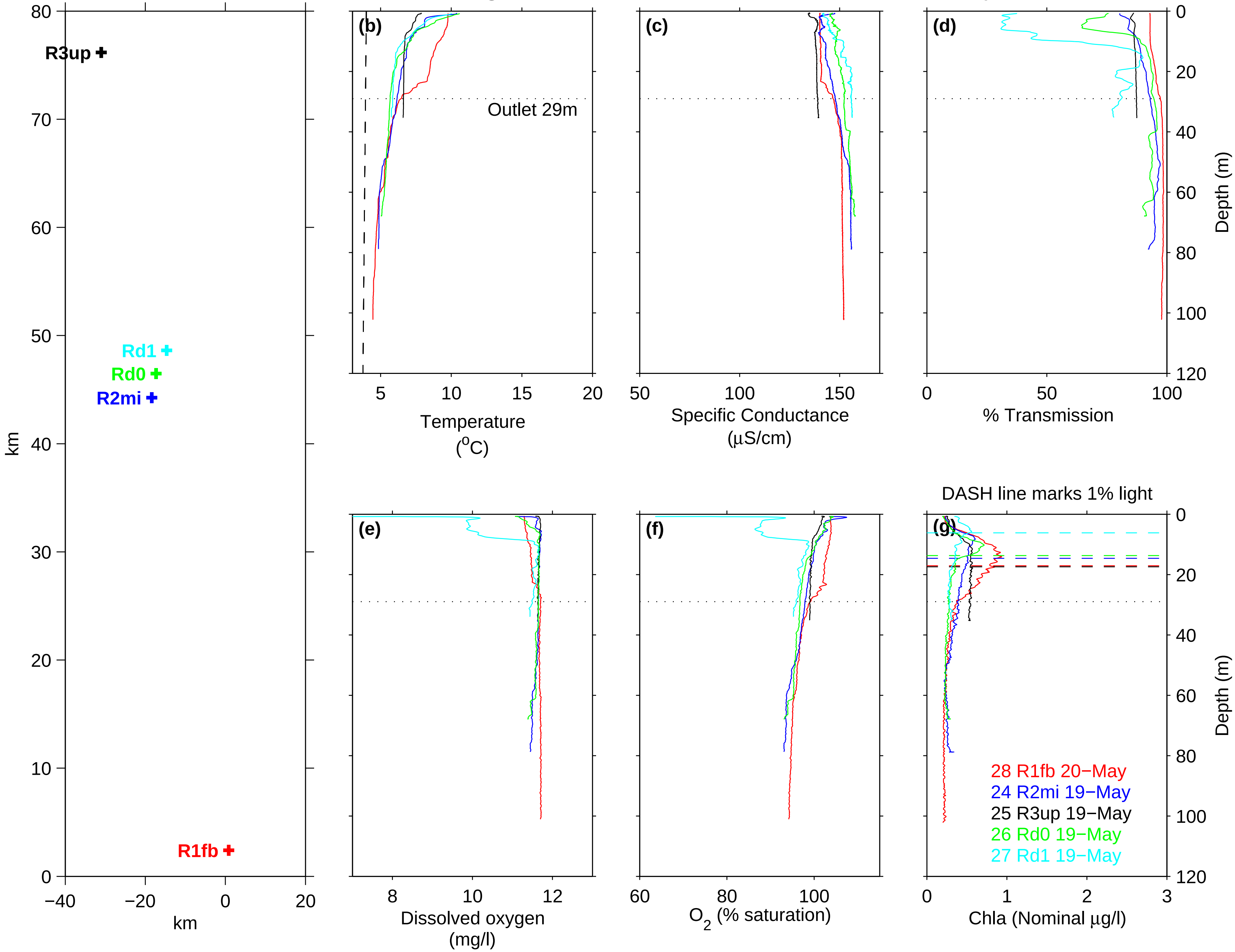


Figure D2.4 Revelstoke Reservoir, 22−25 Jun 2015

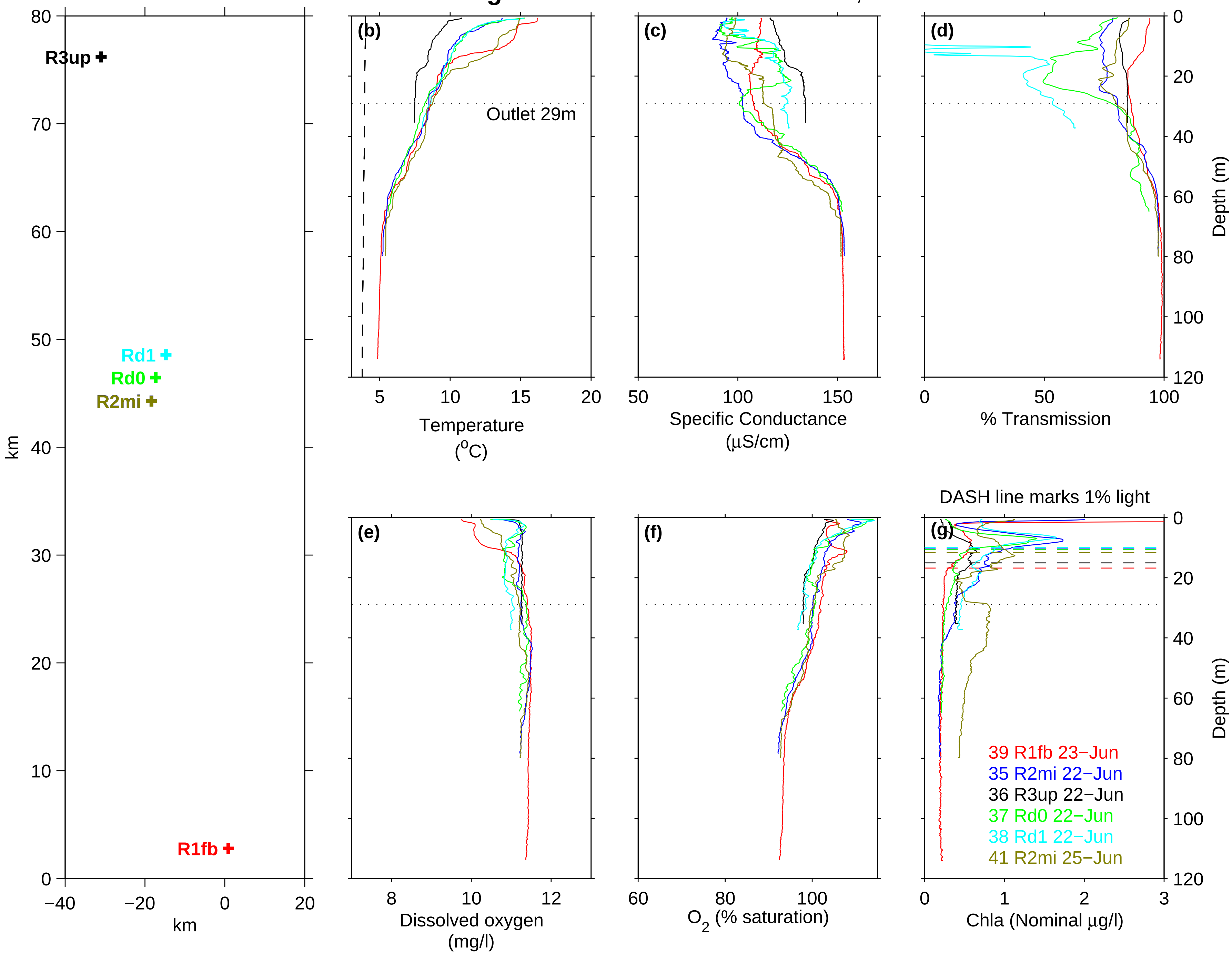


Figure D2.5 Revelstoke Reservoir, 20−24 Jul 2015

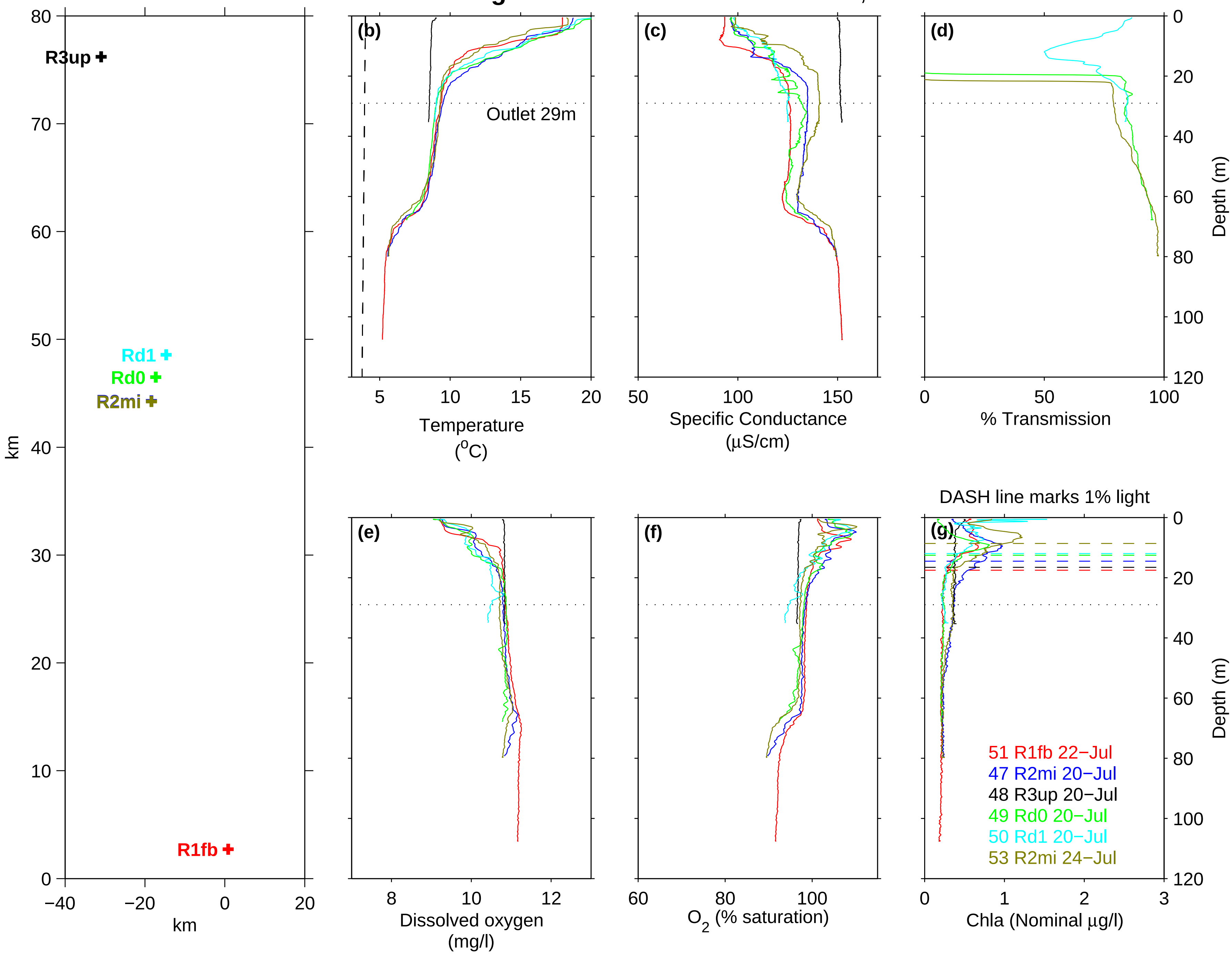


Figure D2.6 Revelstoke Reservoir, 12 Aug 2015

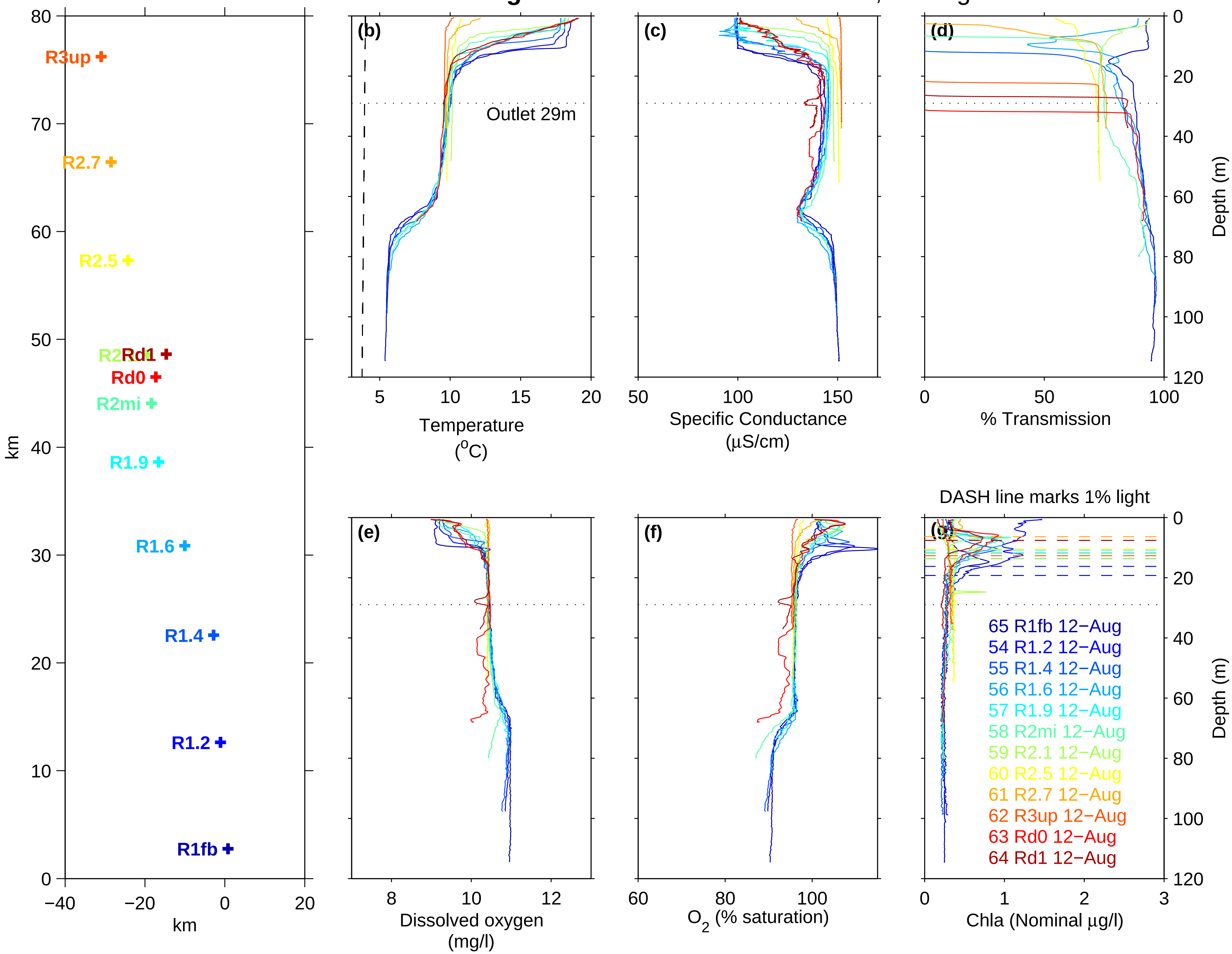


Figure D2.7 Revelstoke Reservoir, 24−27 Aug 2015

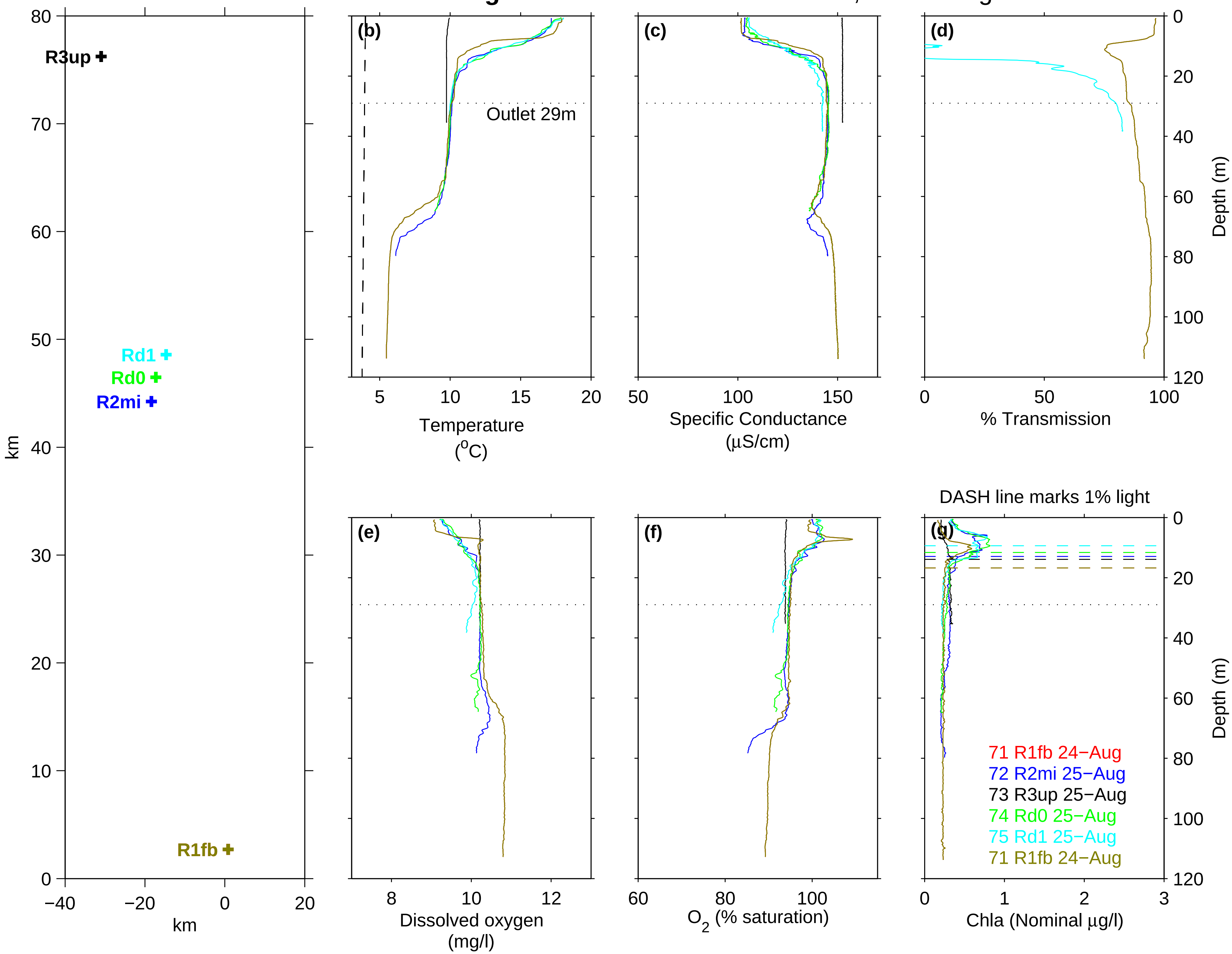


Figure D2.8 Revelstoke Reservoir, 14−15 Sep 2015

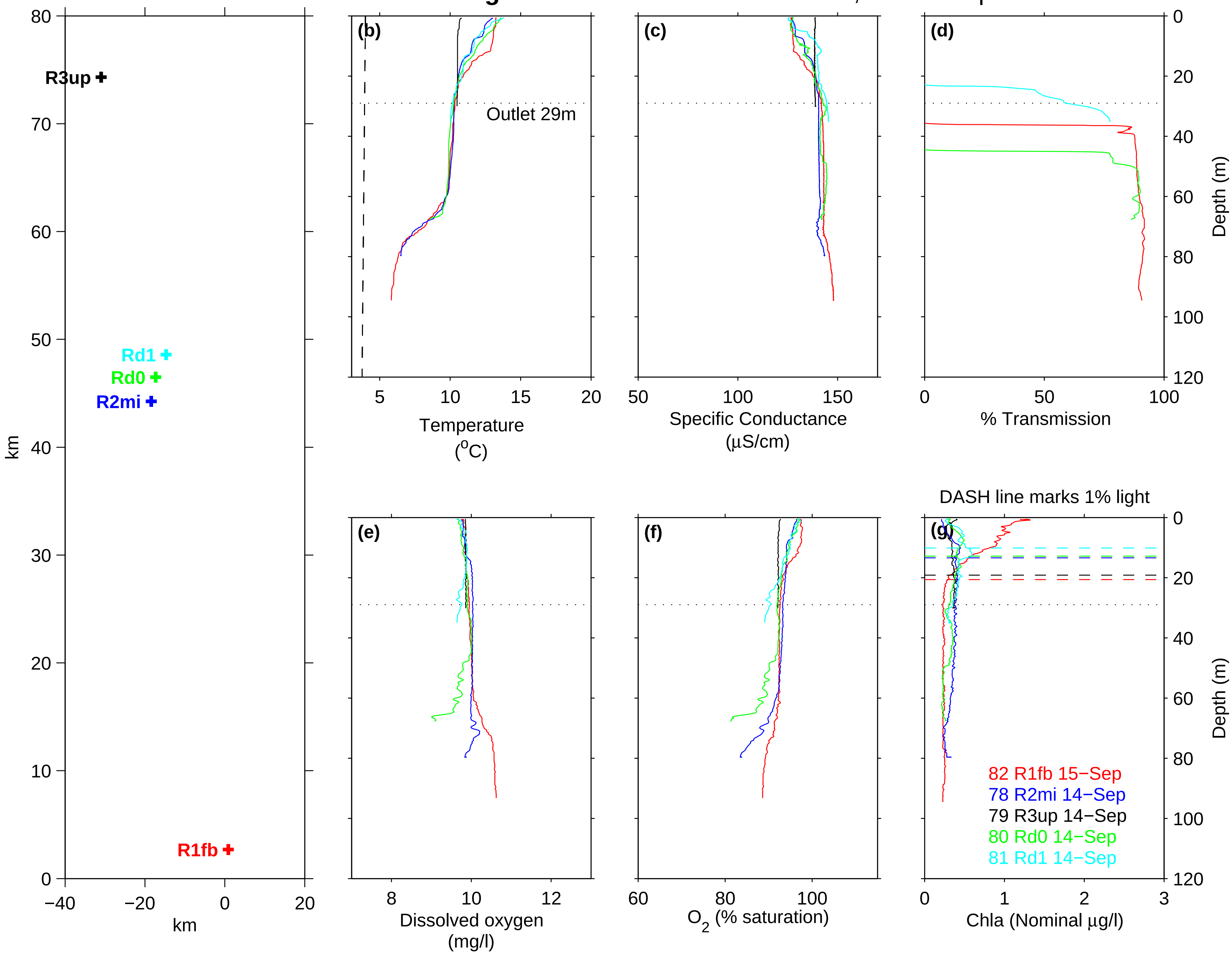


Figure D2.9 Revelstoke Reservoir, 29 Sep 2015

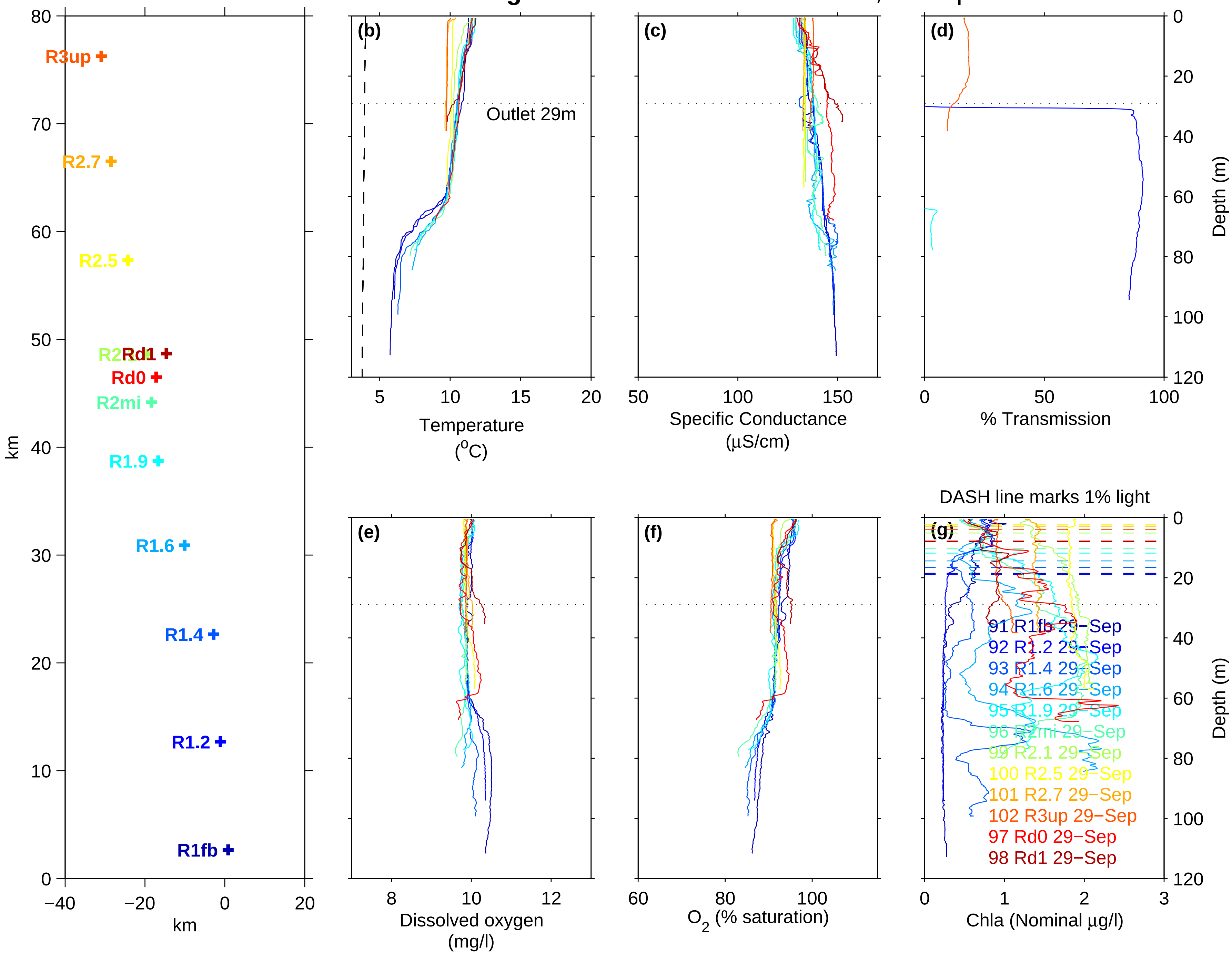


Figure D2.10 Revelstoke Reservoir, 19−20 Oct 2015

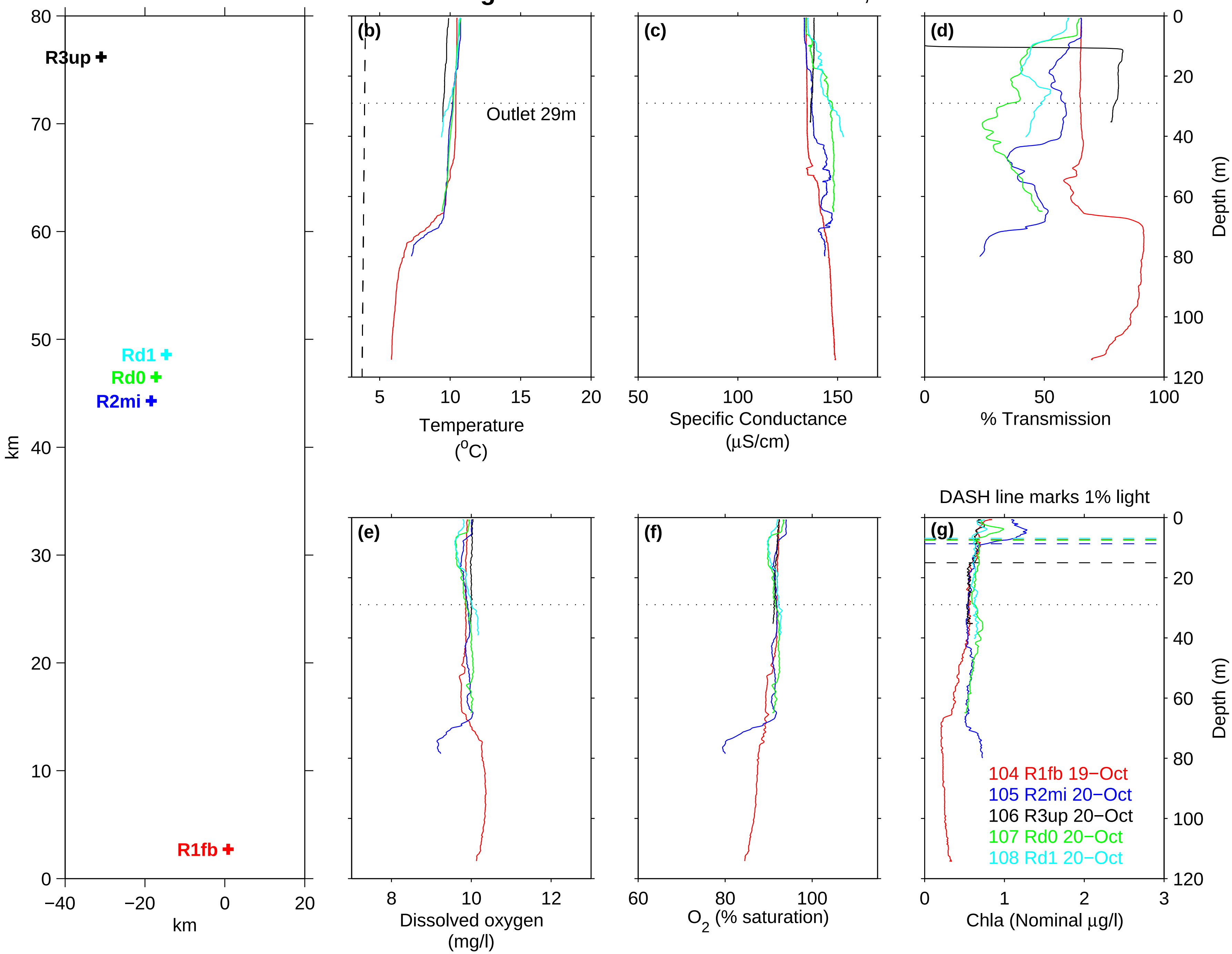


Figure D2.11 Revelstoke Reservoir, Forebay 2015

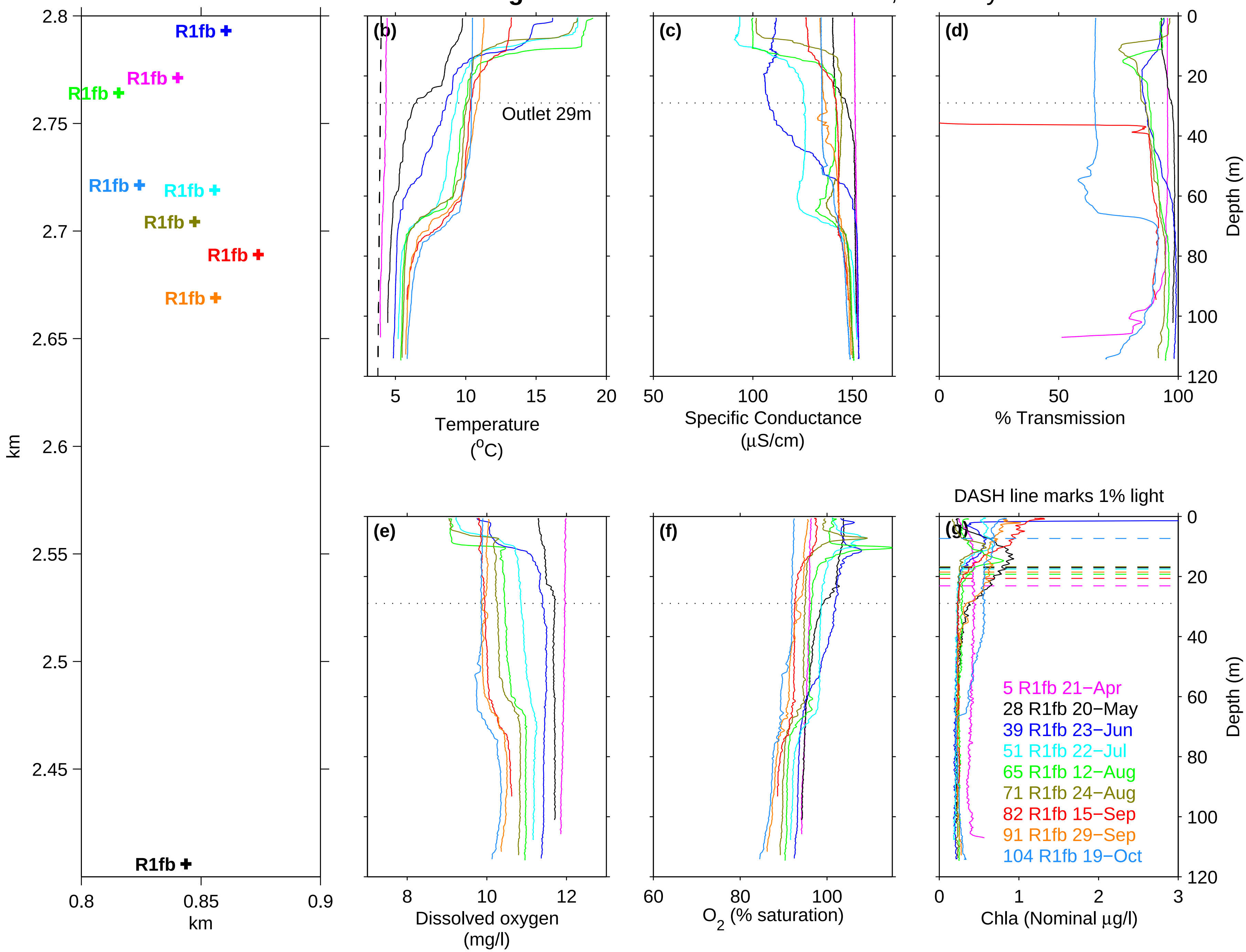


Figure D2.12 Revelstoke Reservoir, Middle 2015

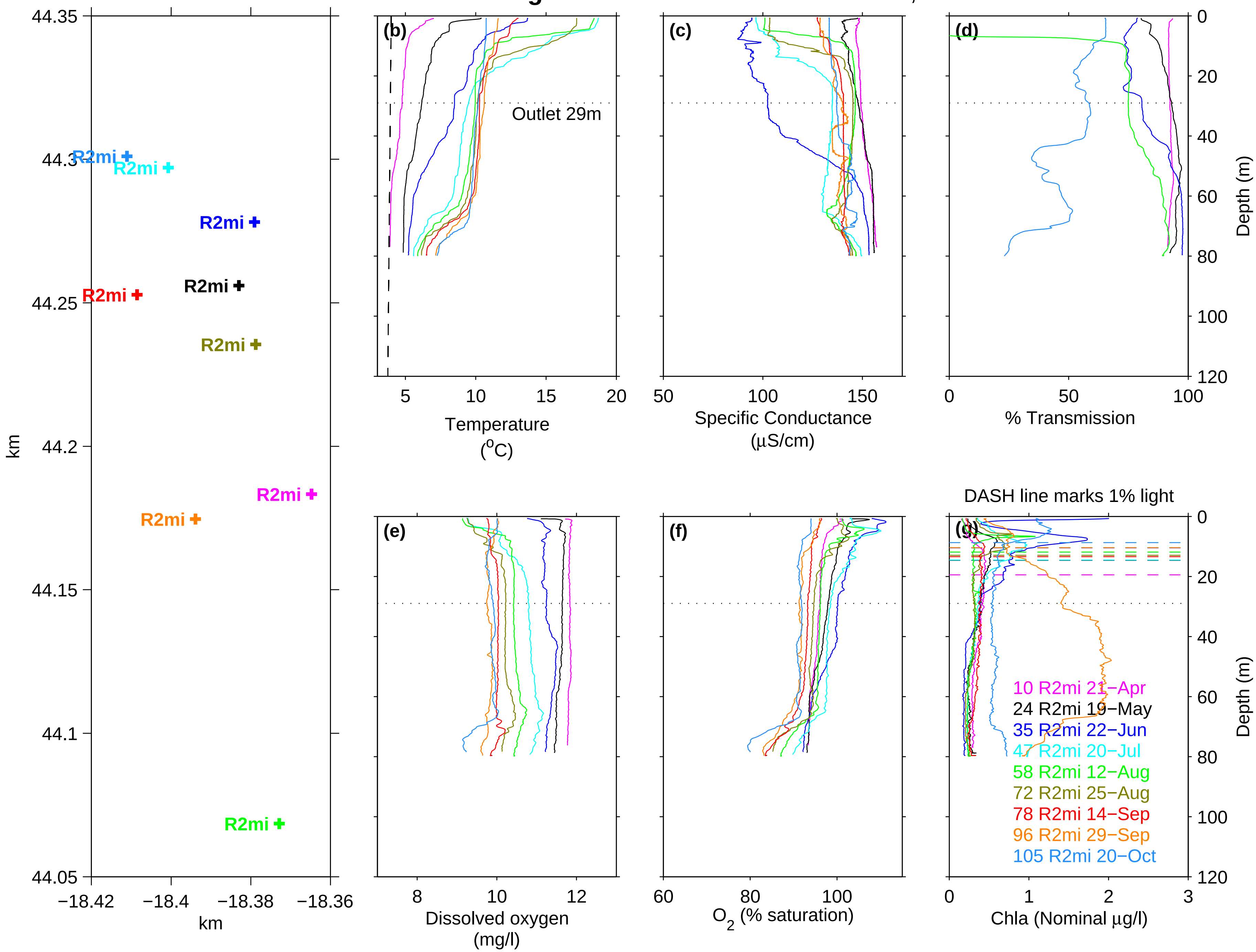


Figure D2.13 Revelstoke Reservoir, Upper 2015

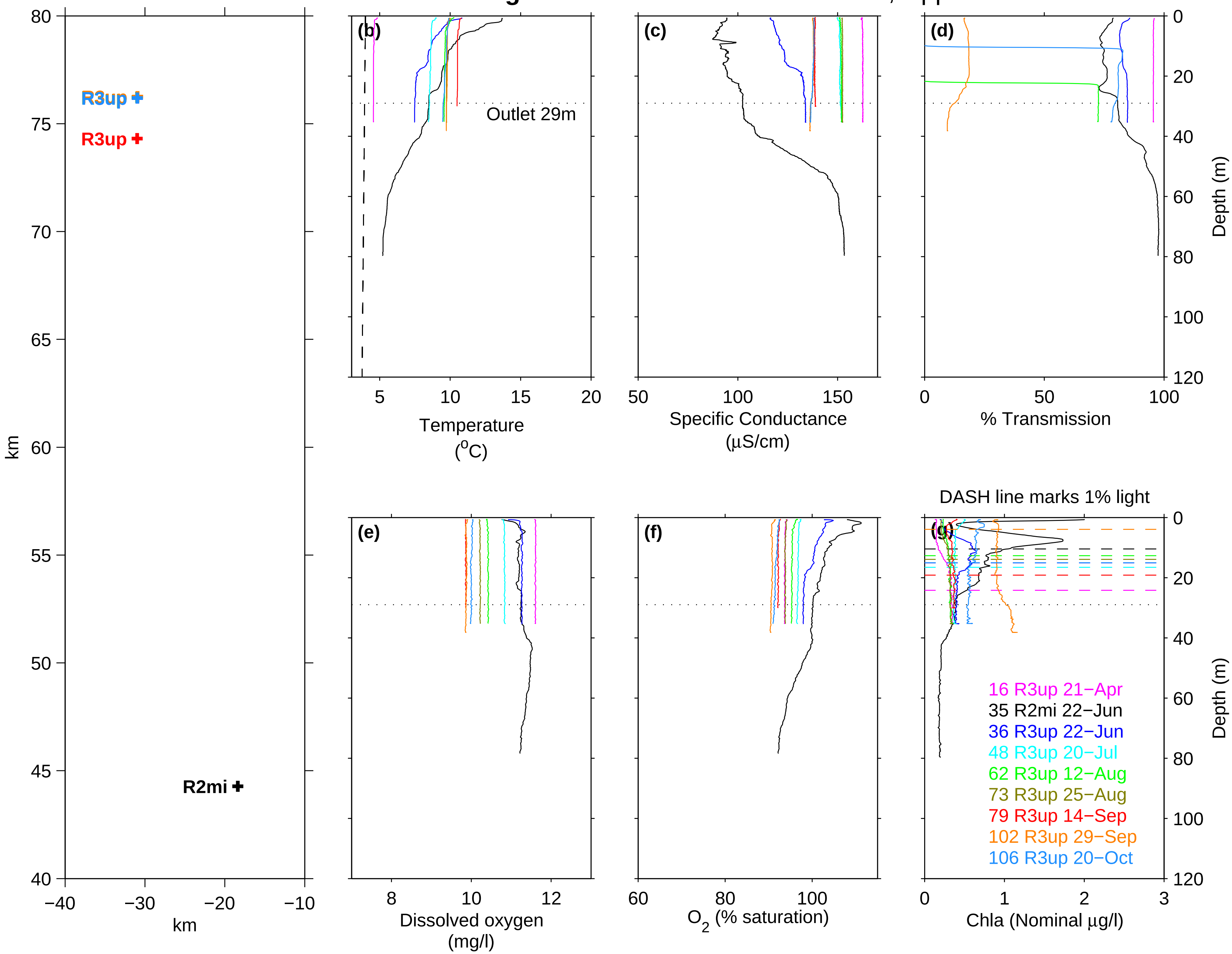


Figure D2.14 Revelstoke Reservoir, Downie Arm 2015

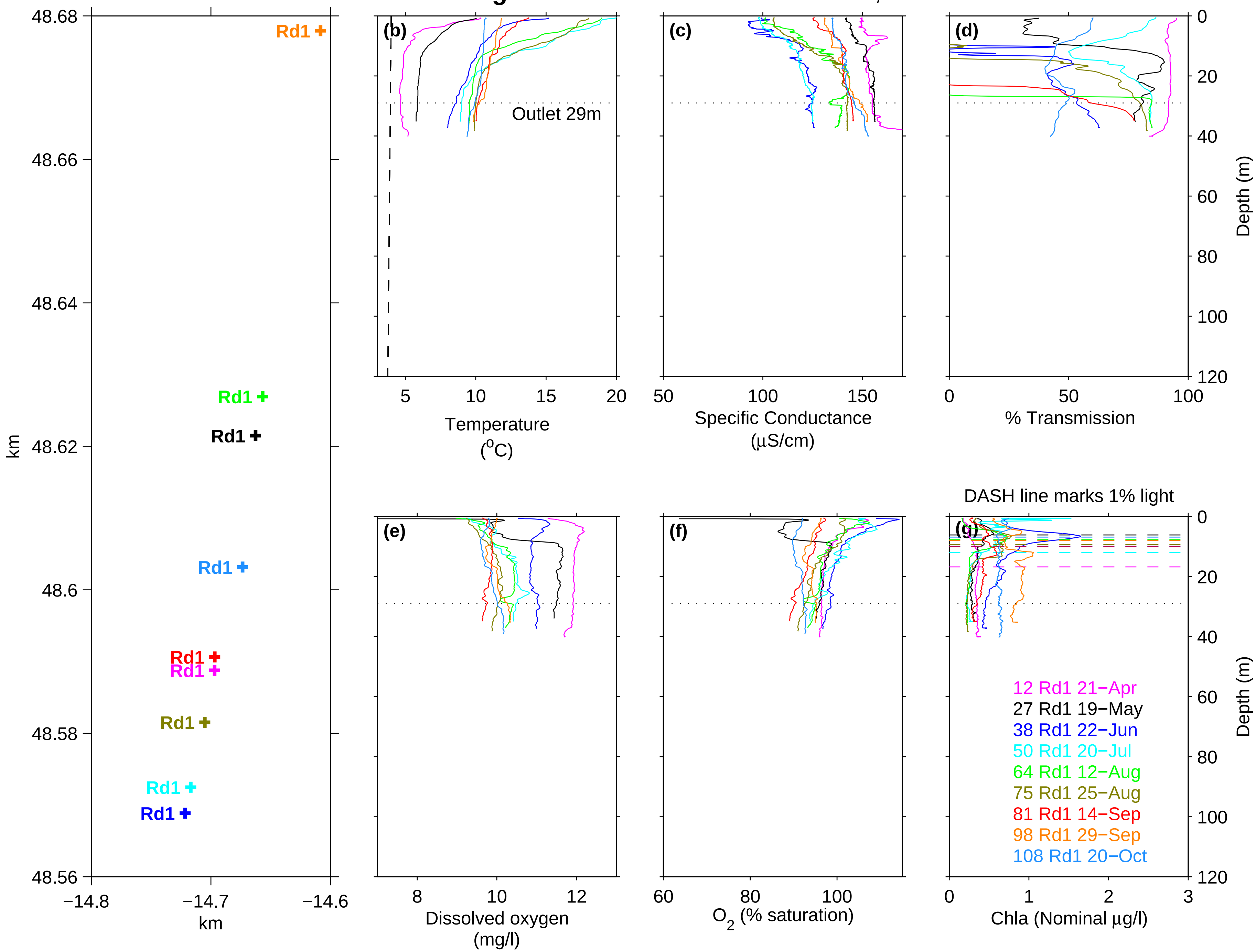


Figure E1.1 Revelstoke Reservoir 21 May, 2014

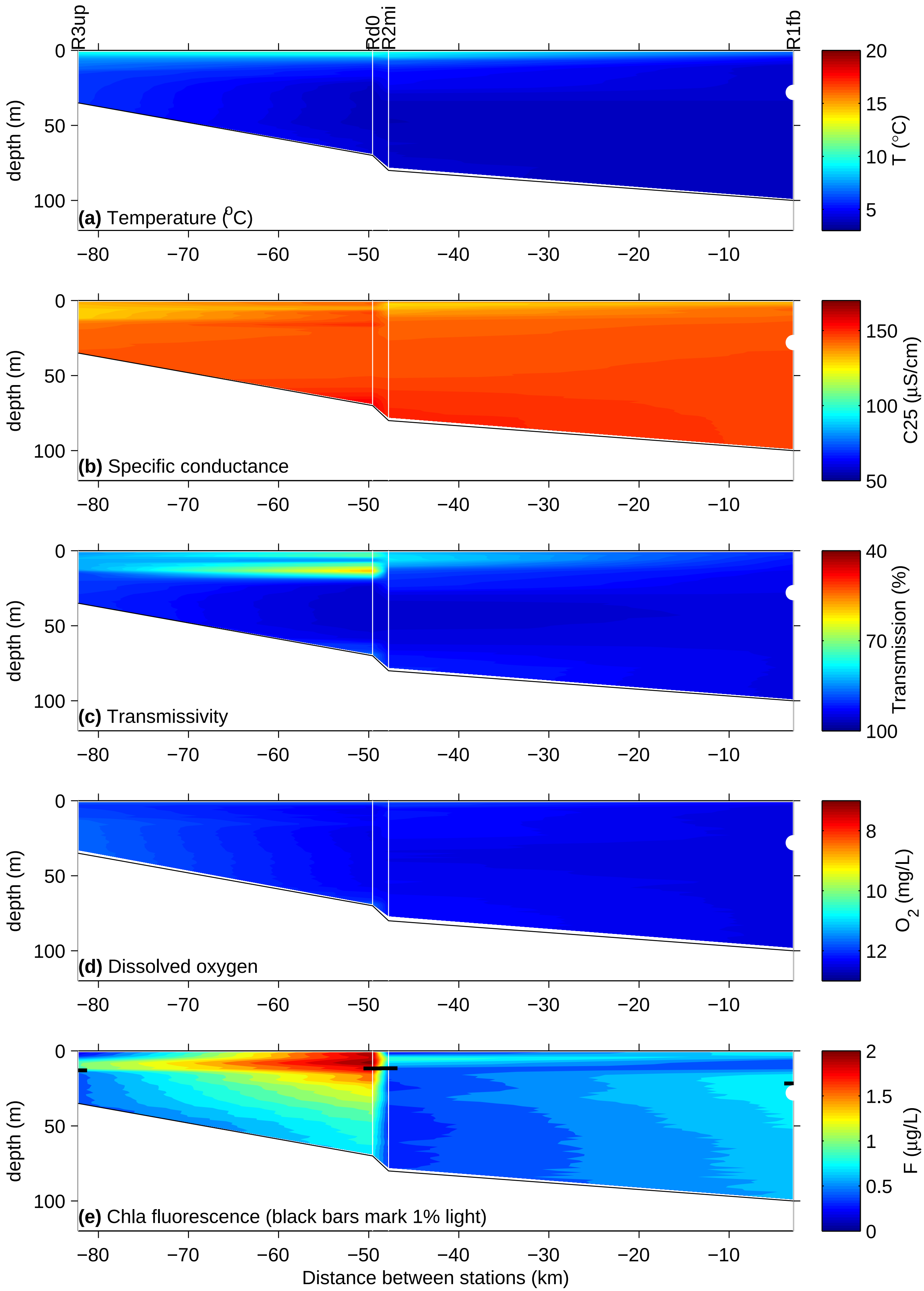


Figure E1.2 Revelstoke Reservoir 11 Jun, 2014

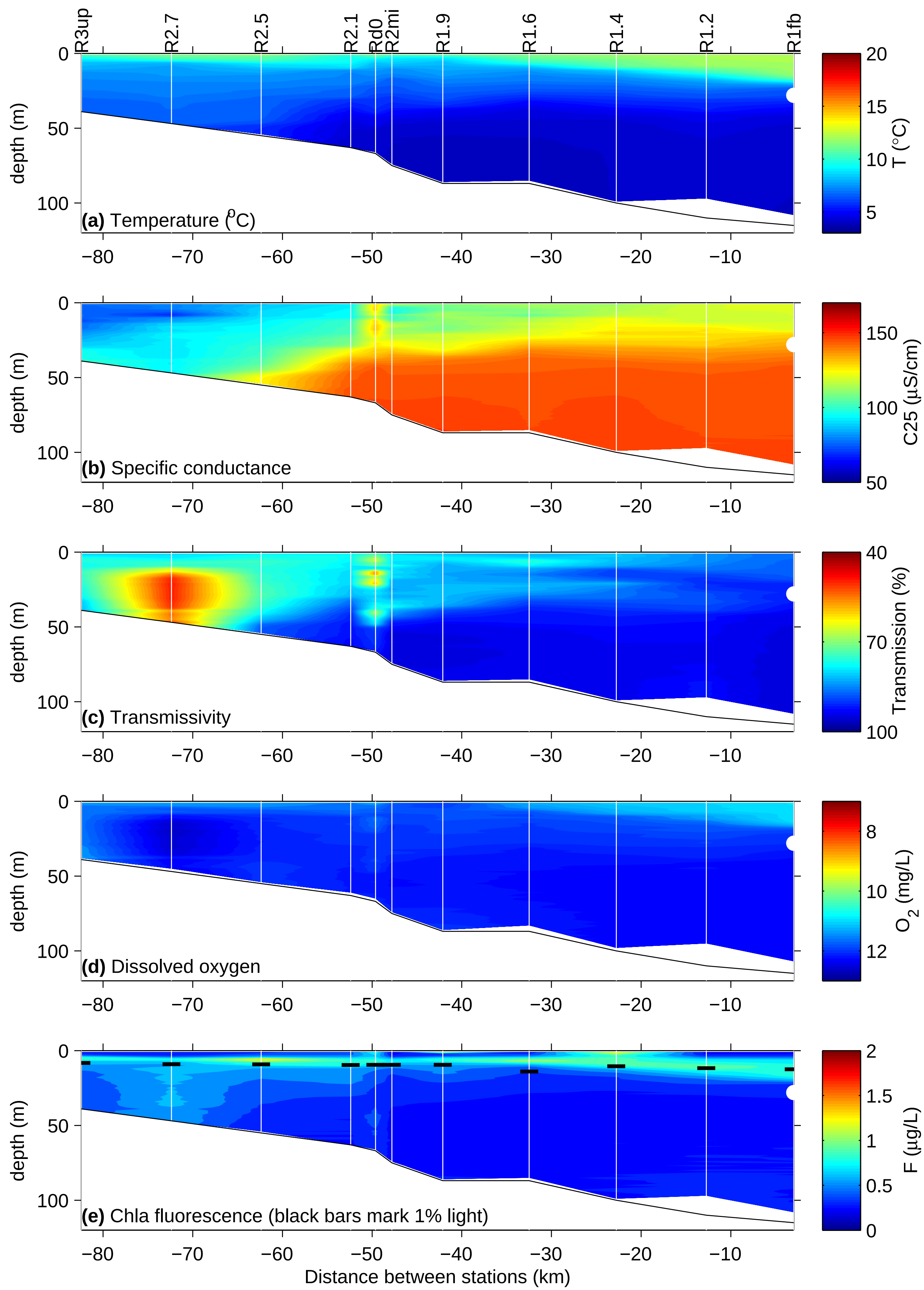


Figure E1.3 Revelstoke Reservoir 23−24 Jun, 2014

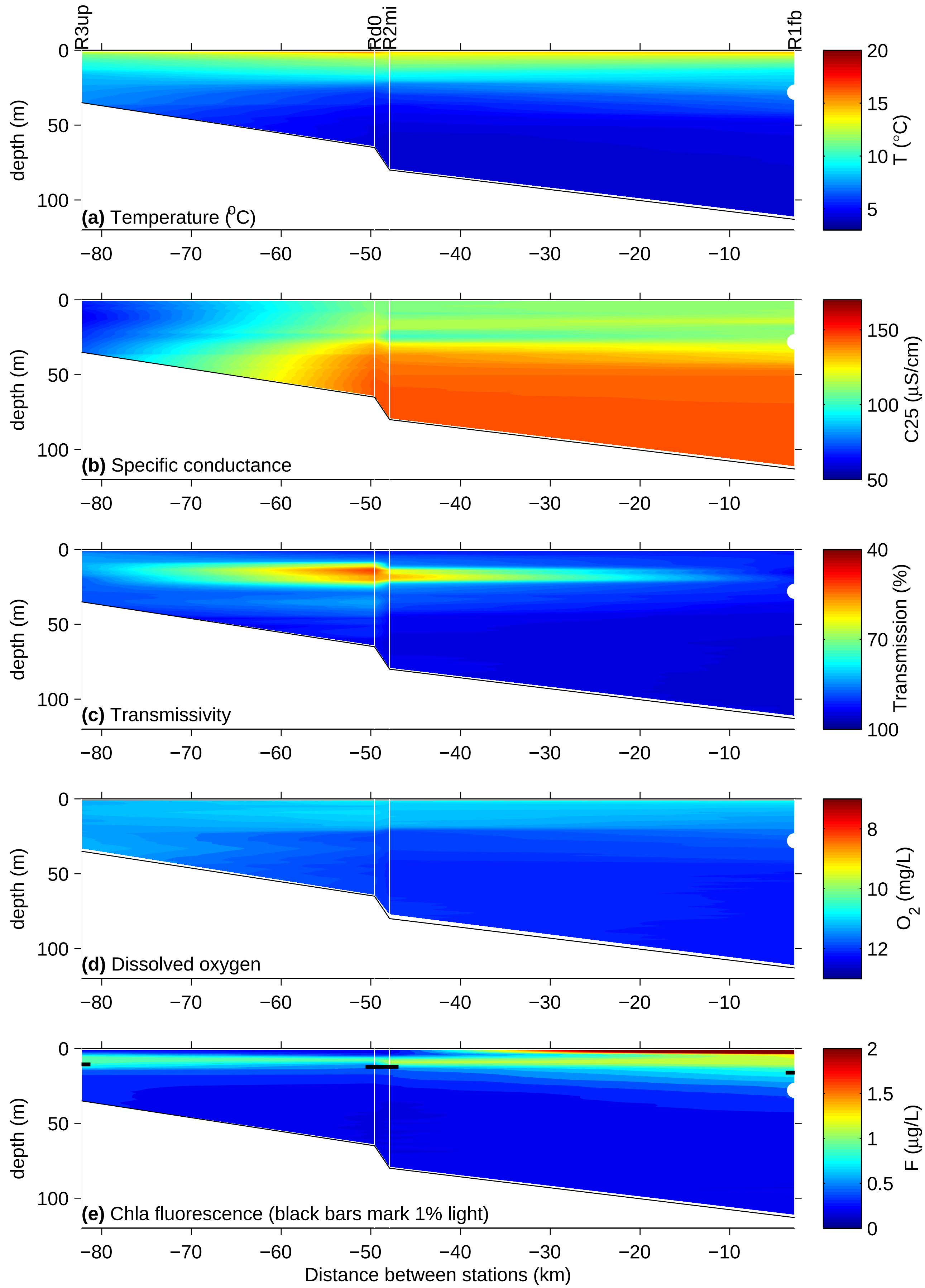


Figure E1.4 Revelstoke Reservoir 18−19 Aug, 2014

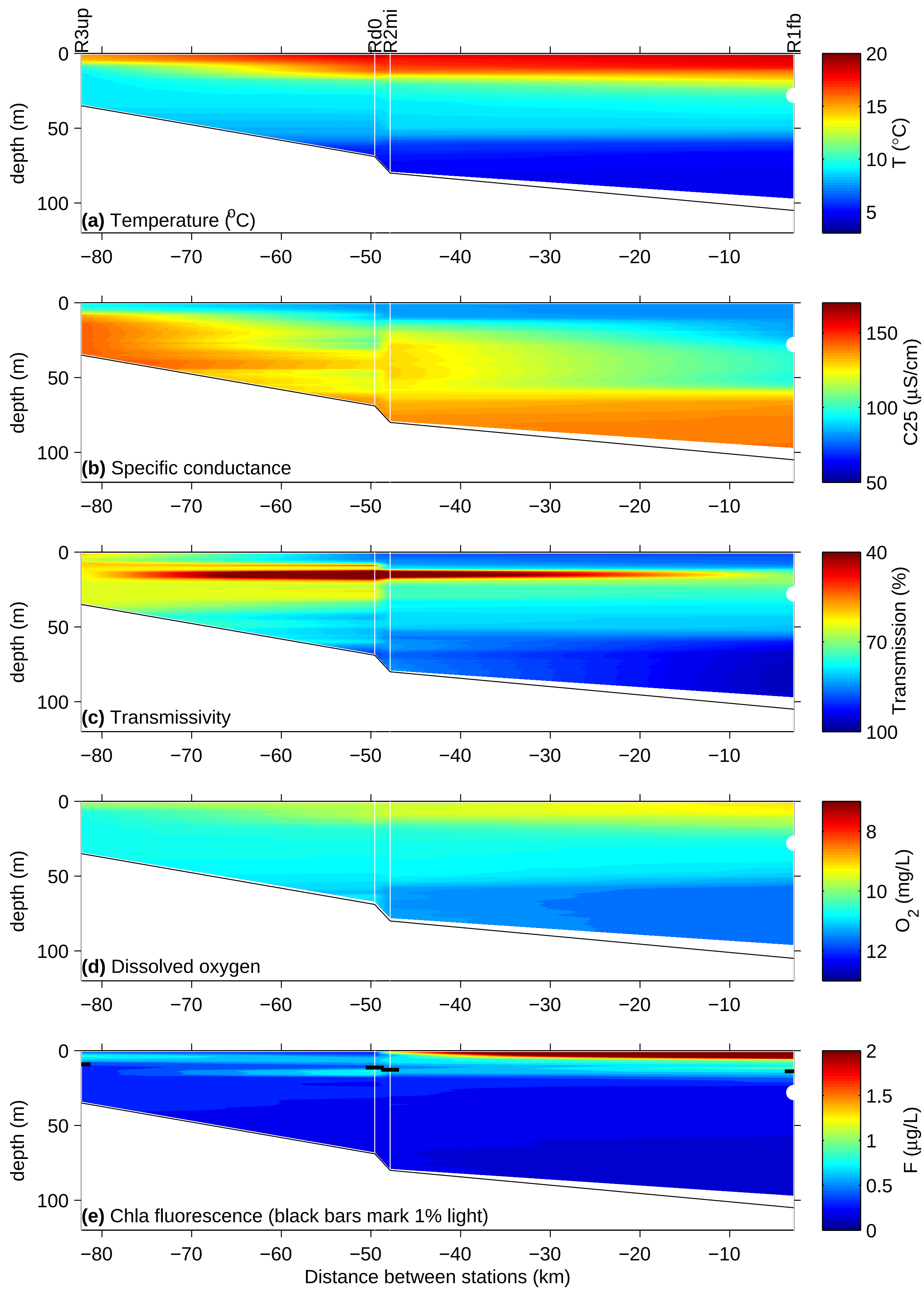


Figure E1.5 Revelstoke Reservoir 22−23 Sep, 2014

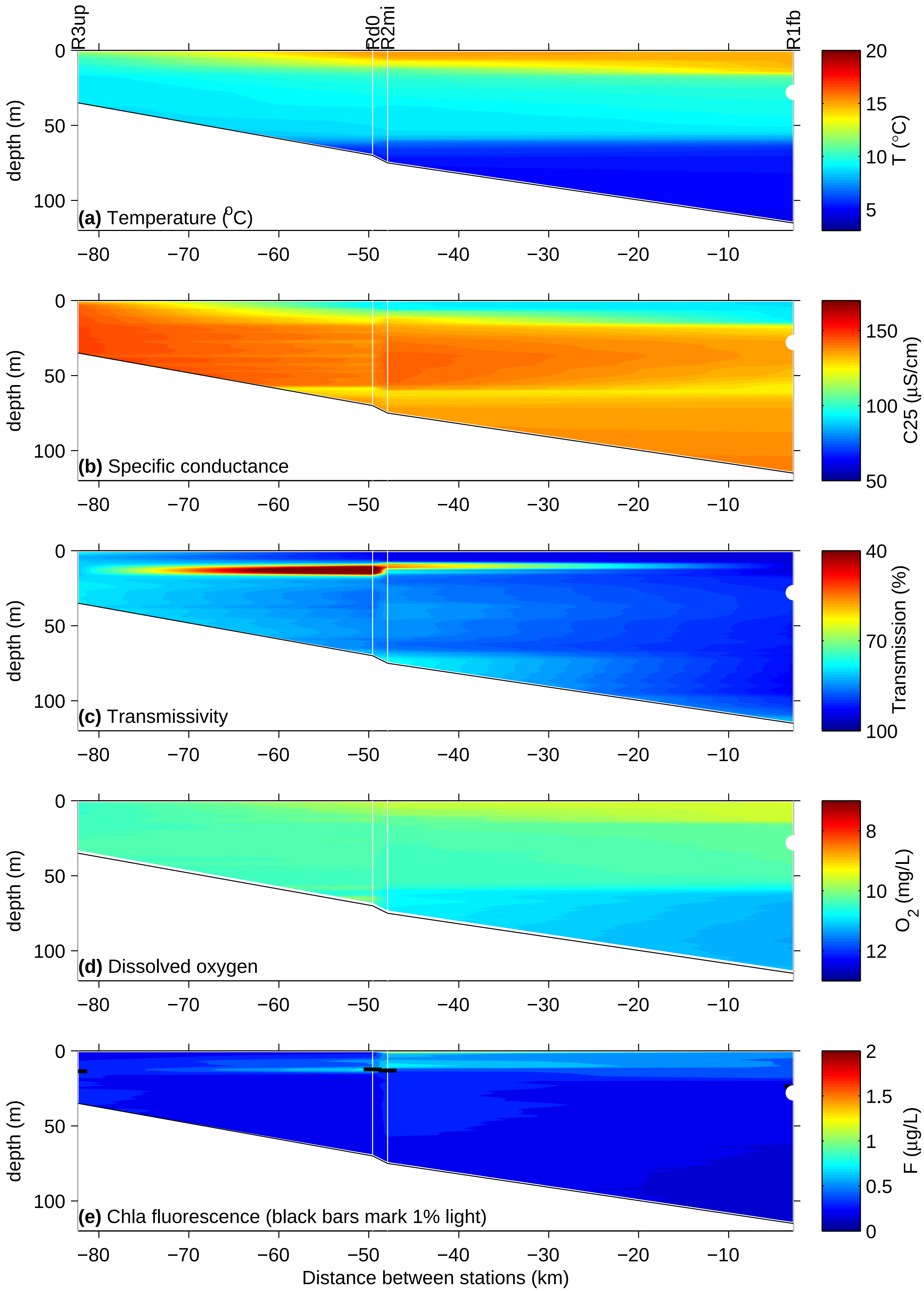


Figure E1.6 Revelstoke Reservoir 14−15 Oct, 2014

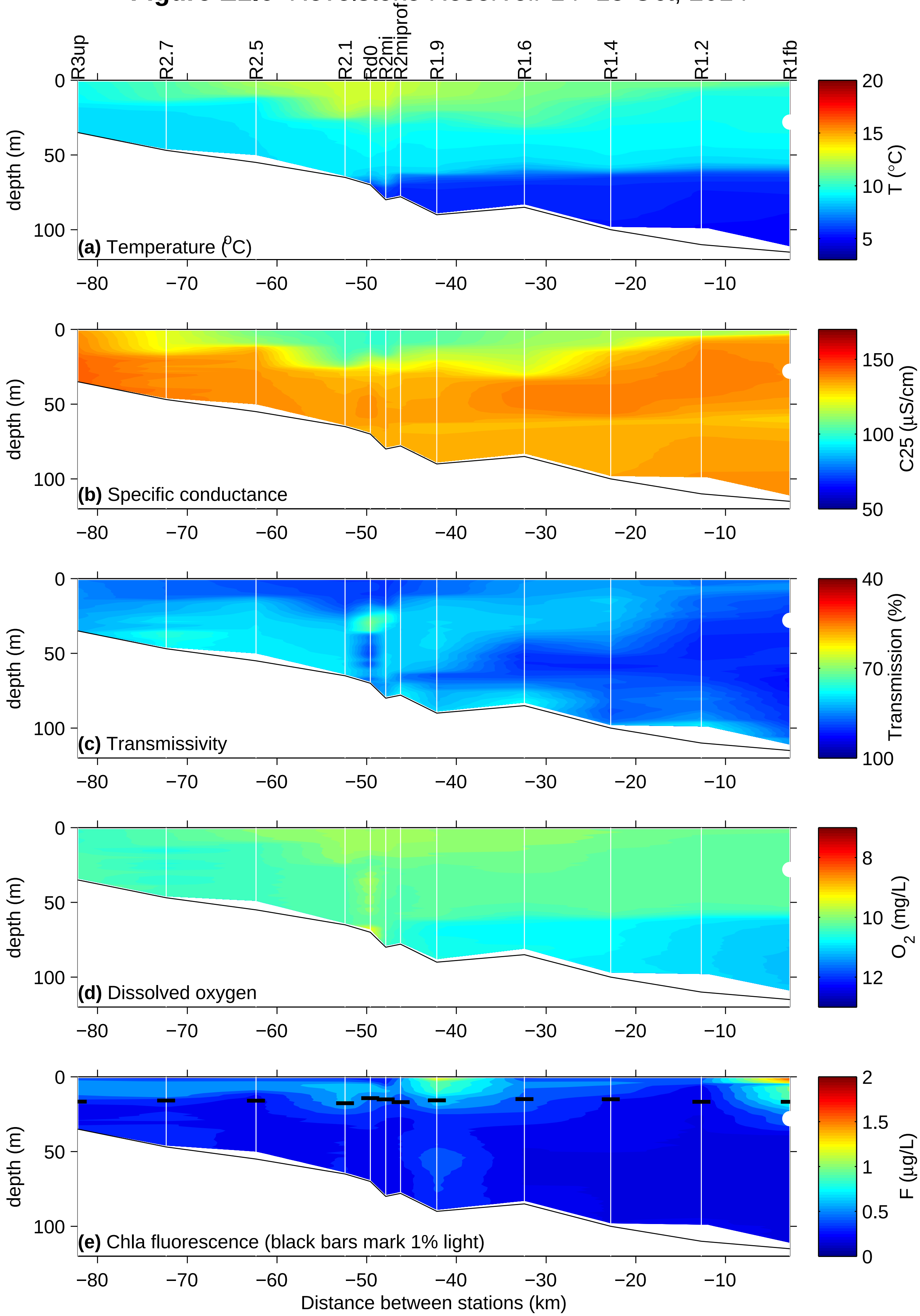


Figure E2.1 Revelstoke Reservoir 21 Apr 2015

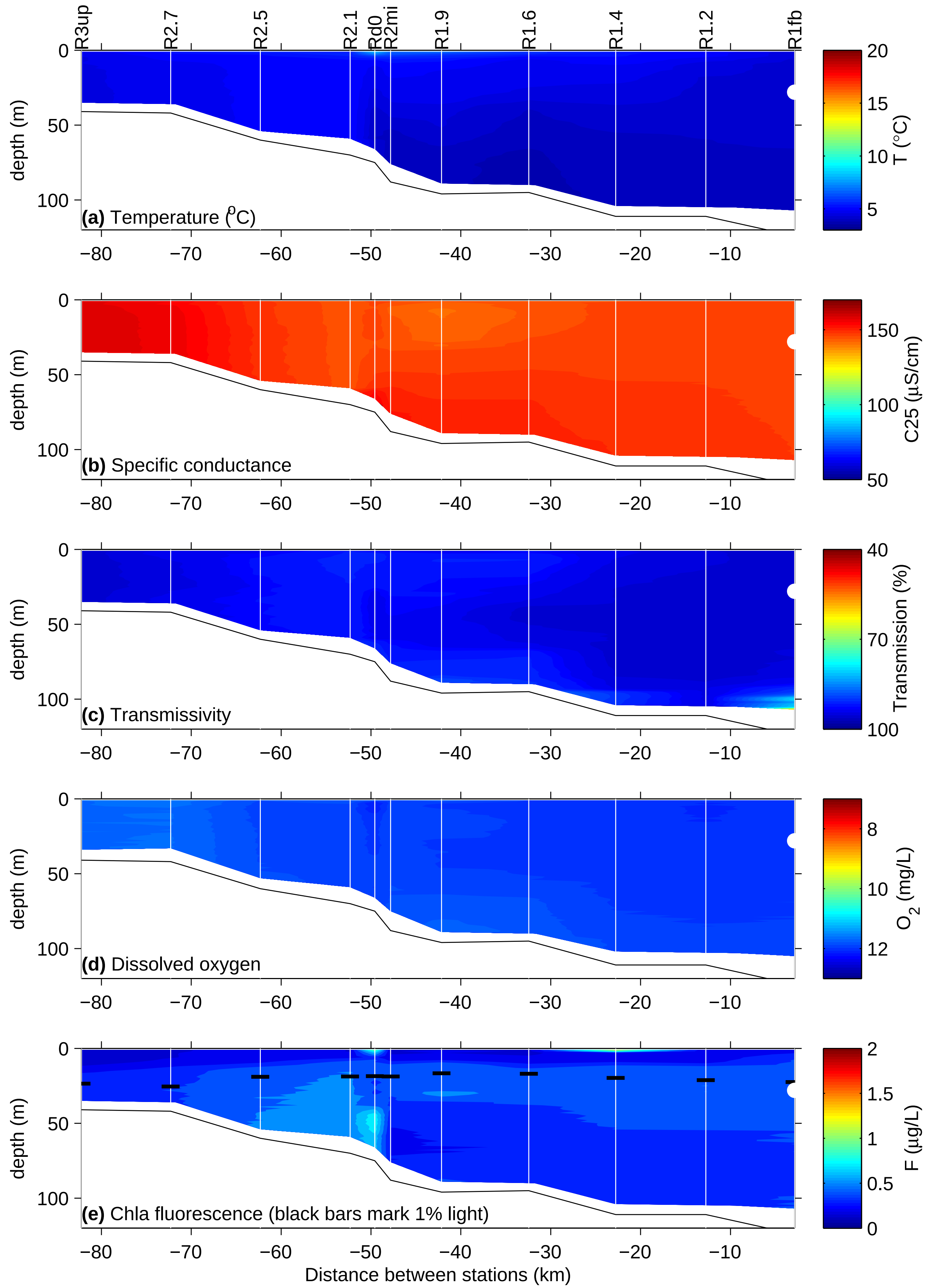


Figure E2.2 Revelstoke Reservoir 19−20 May 2015

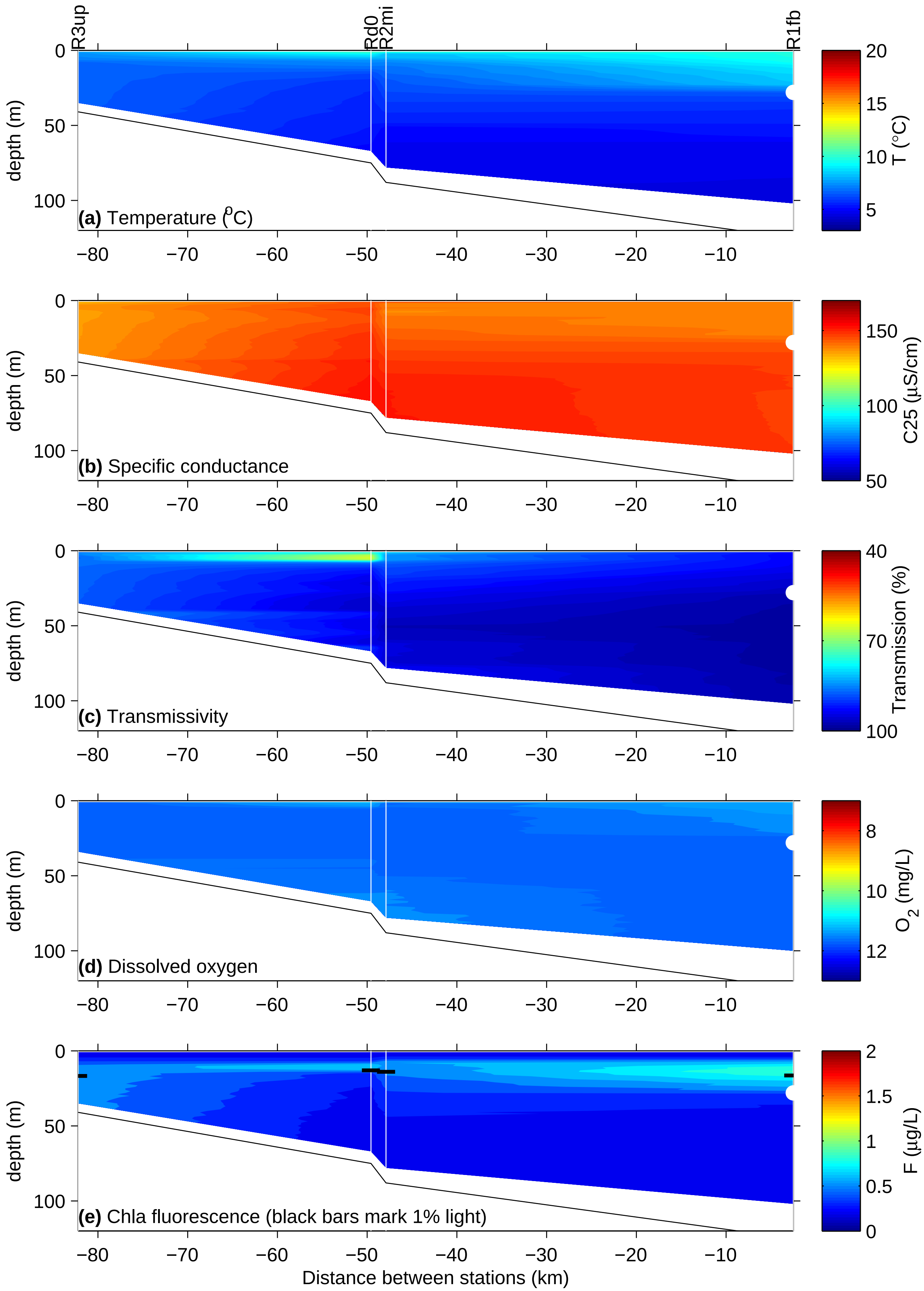


Figure E2.3 Revelstoke Reservoir 22−25 Jun 2015

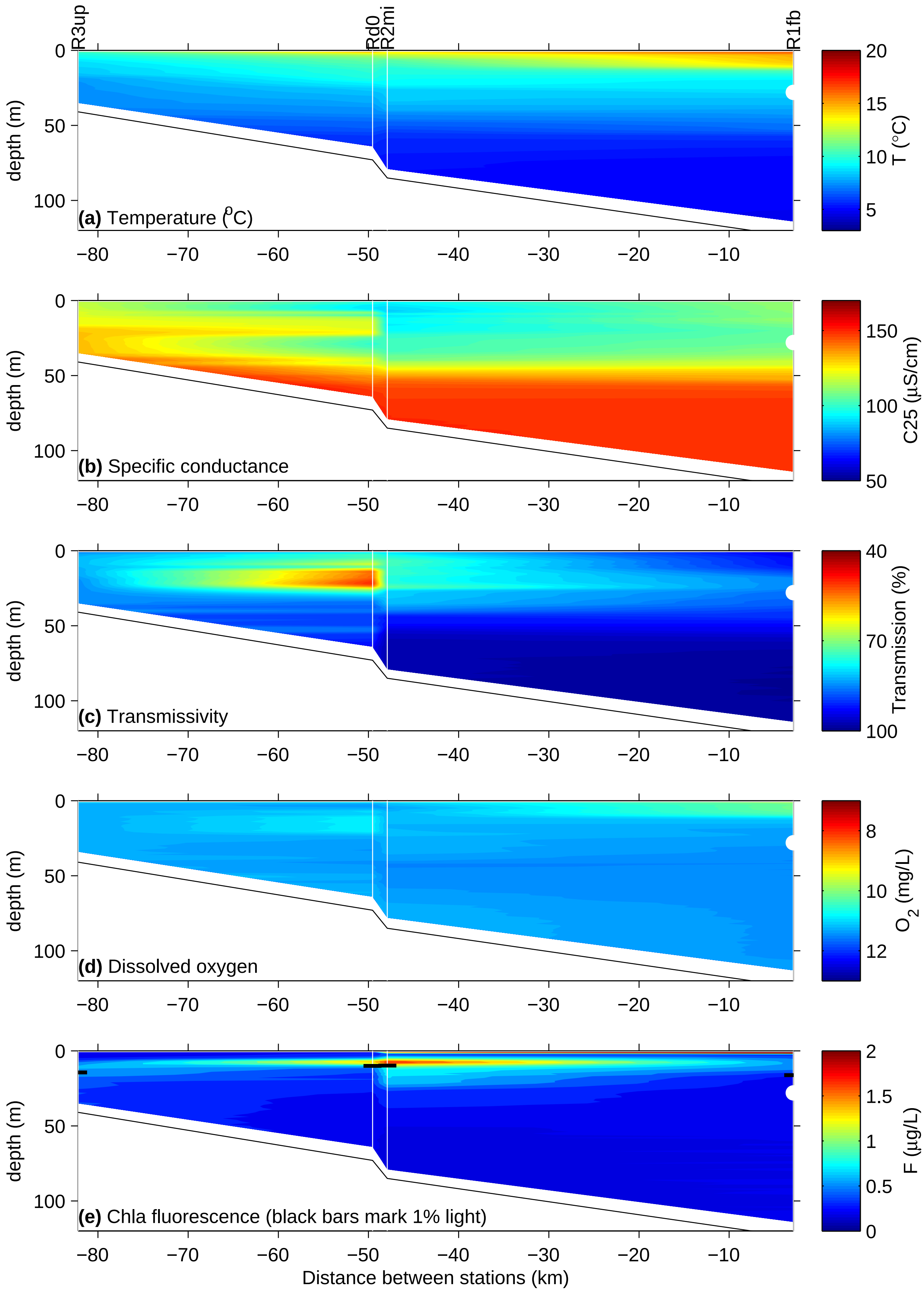


Figure E2.4 Revelstoke Reservoir 20−23 Jul 2015

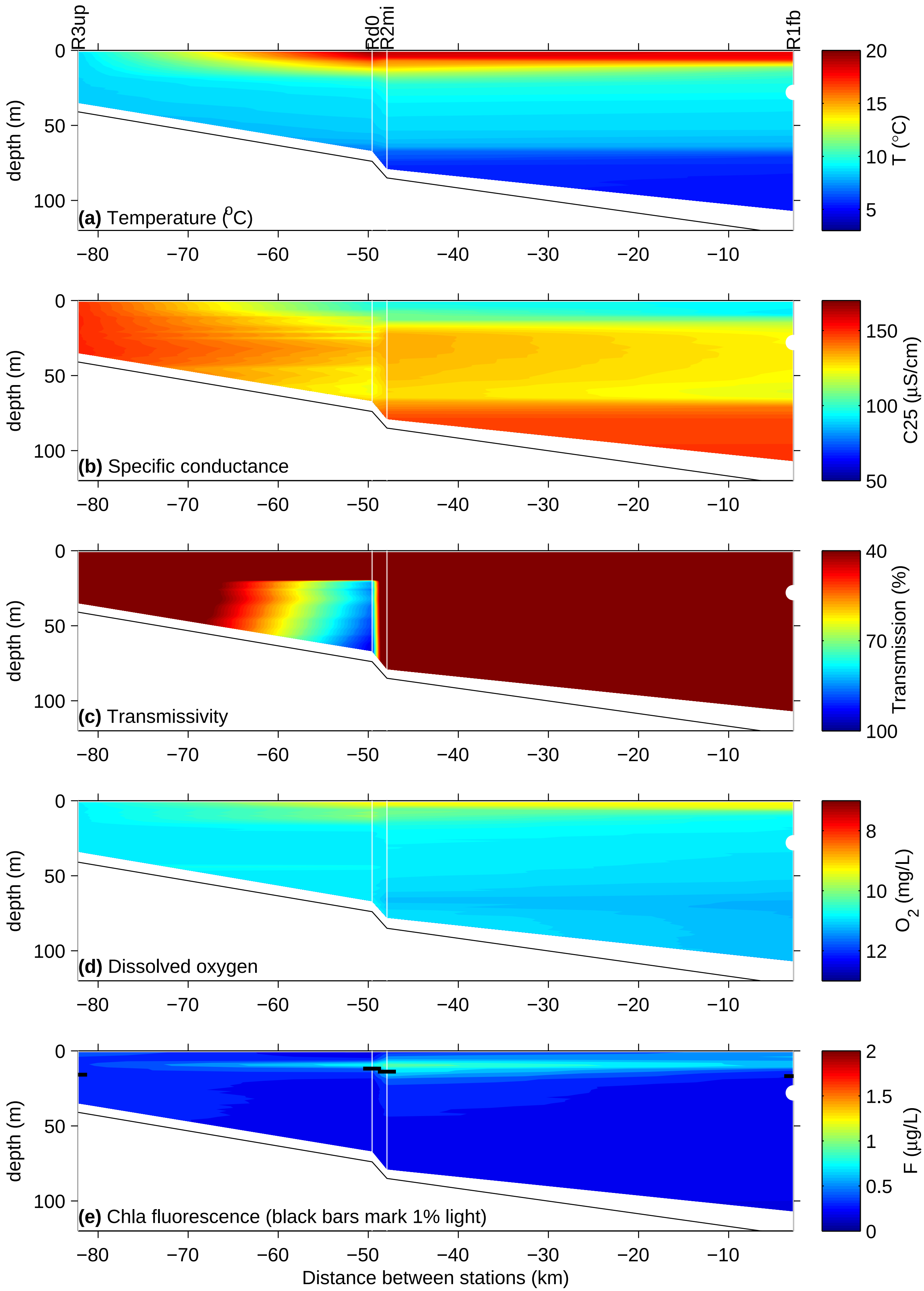


Figure E2.5 Revelstoke Reservoir 12 Aug 2015

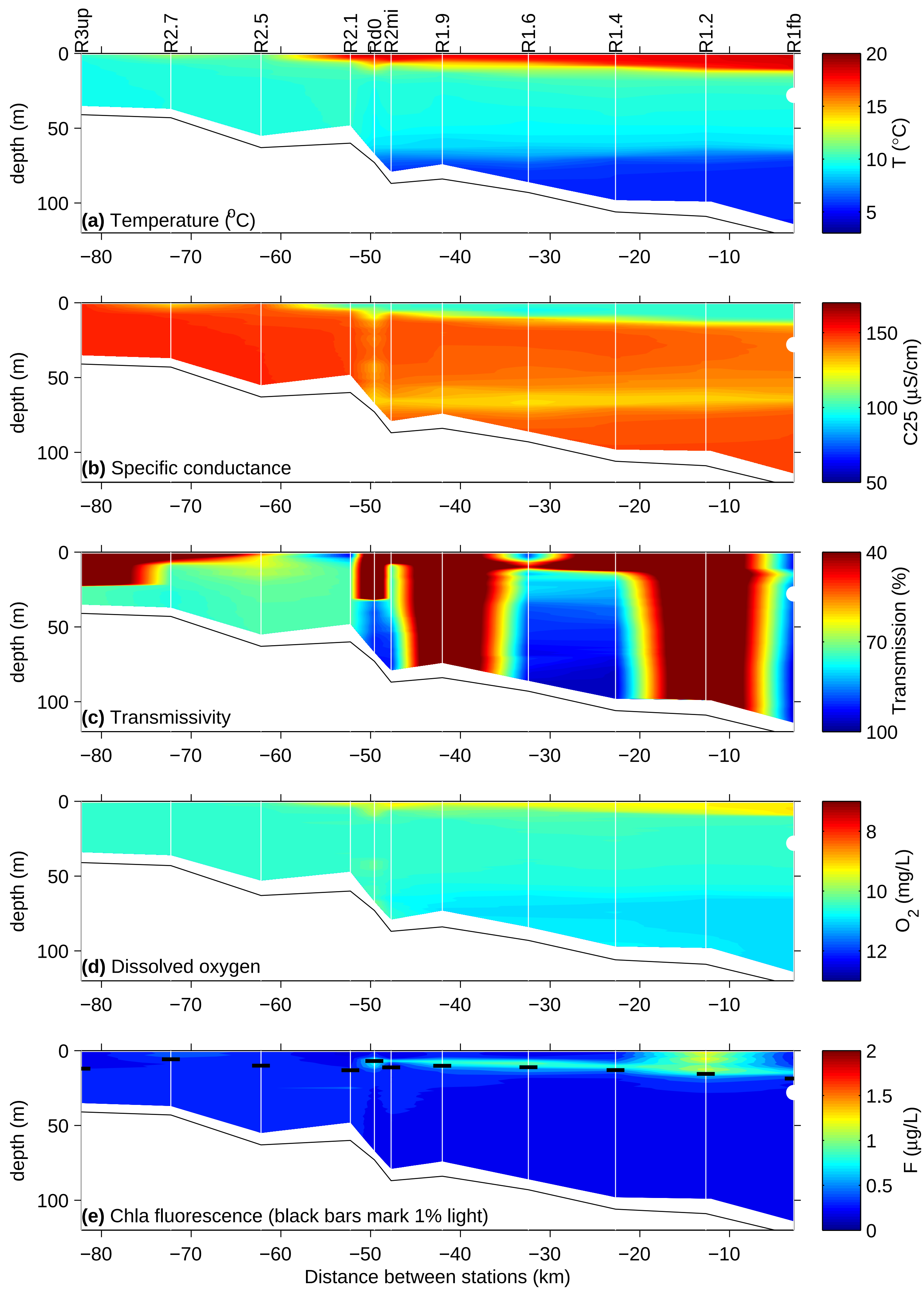


Figure E2.6 Revelstoke Reservoir 24−27 Aug 2015

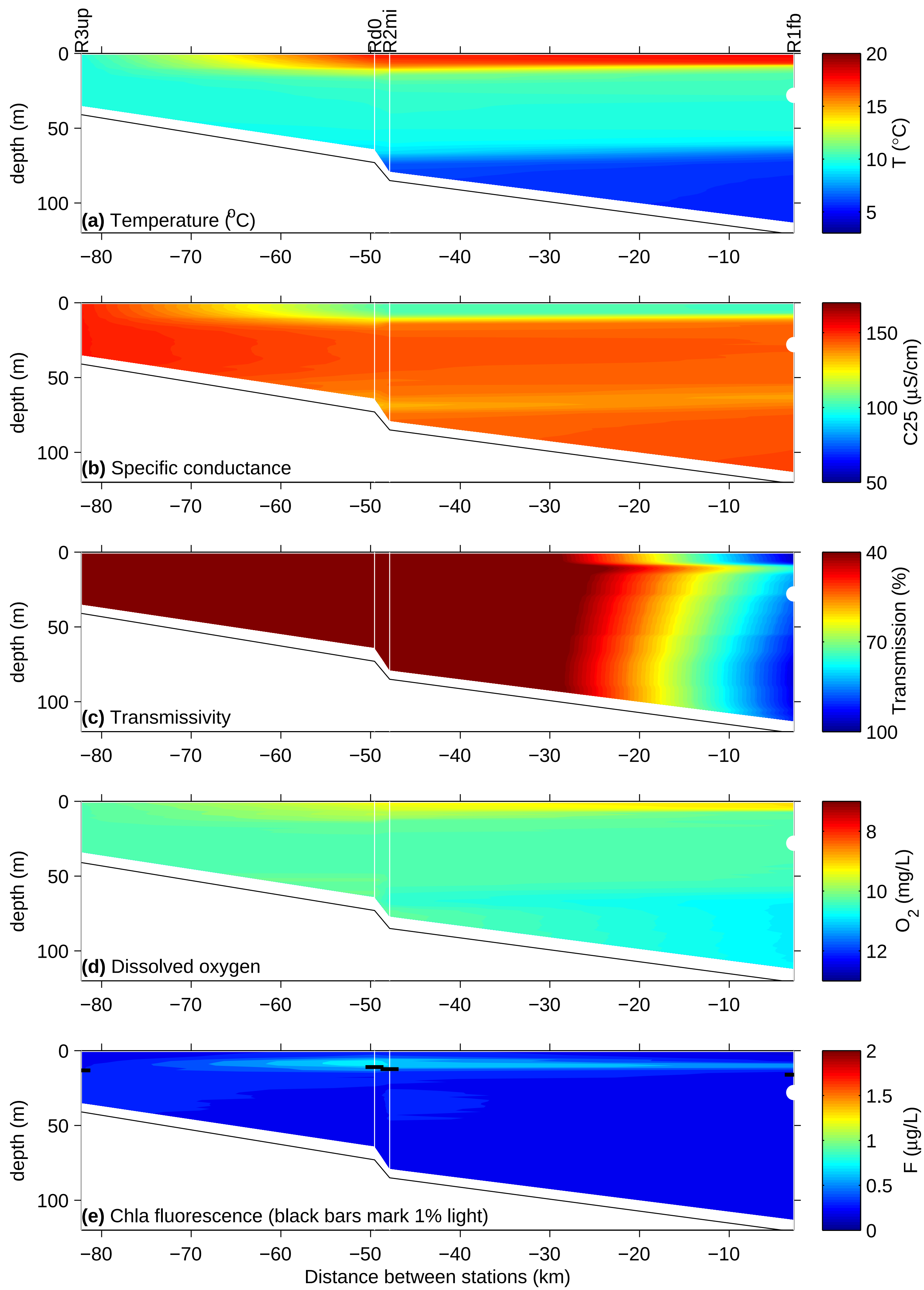


Figure E2.7 Revelstoke Reservoir 14−15 Sep 2015

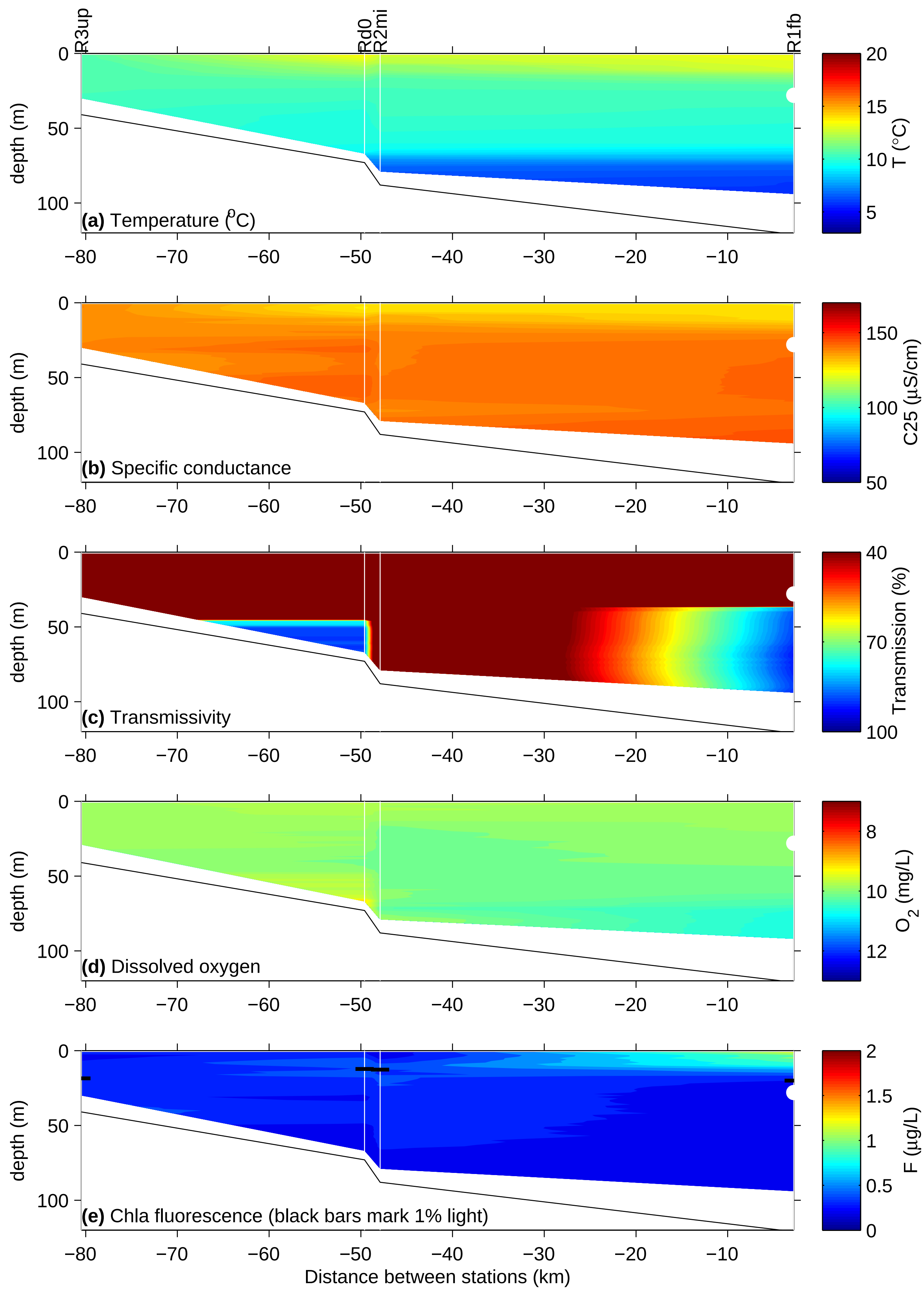


Figure E2.8 Revelstoke Reservoir 29 Sep 2015

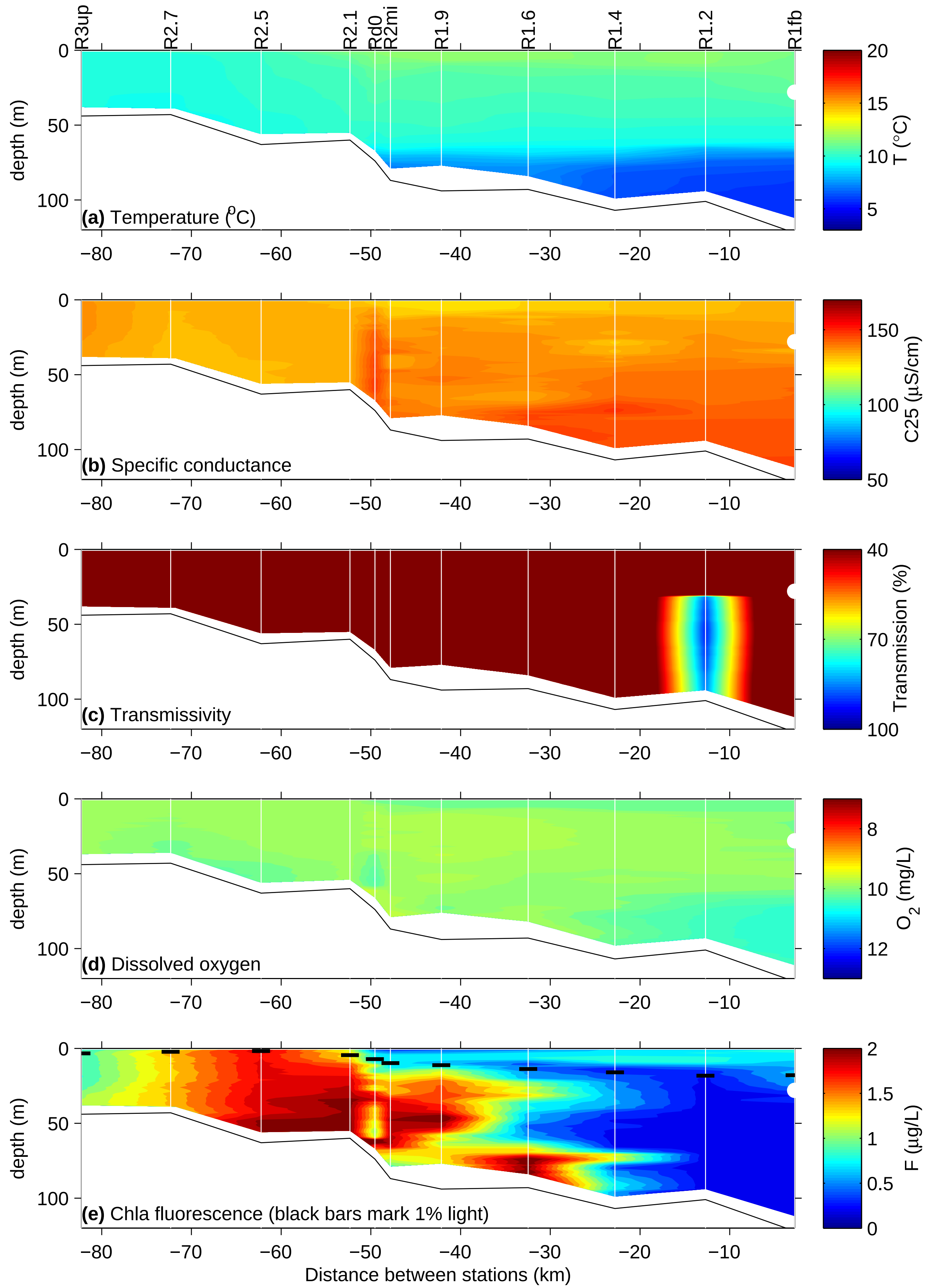


Figure E2.9 Revelstoke Reservoir 19−20 Oct 2015

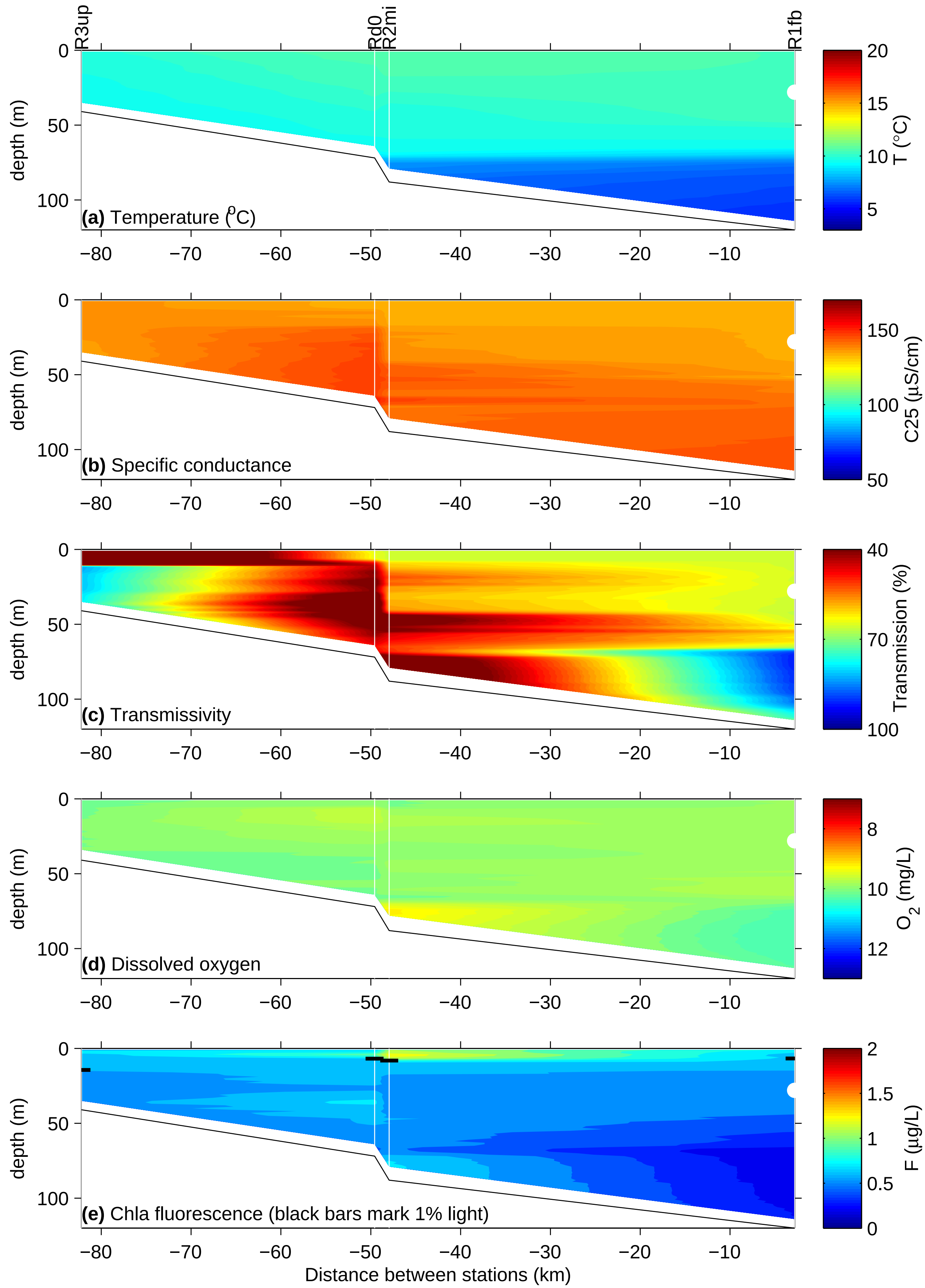


Figure F1.1 All Kinbasket (BLU) and Reveslтoke (RED) Data, 2014

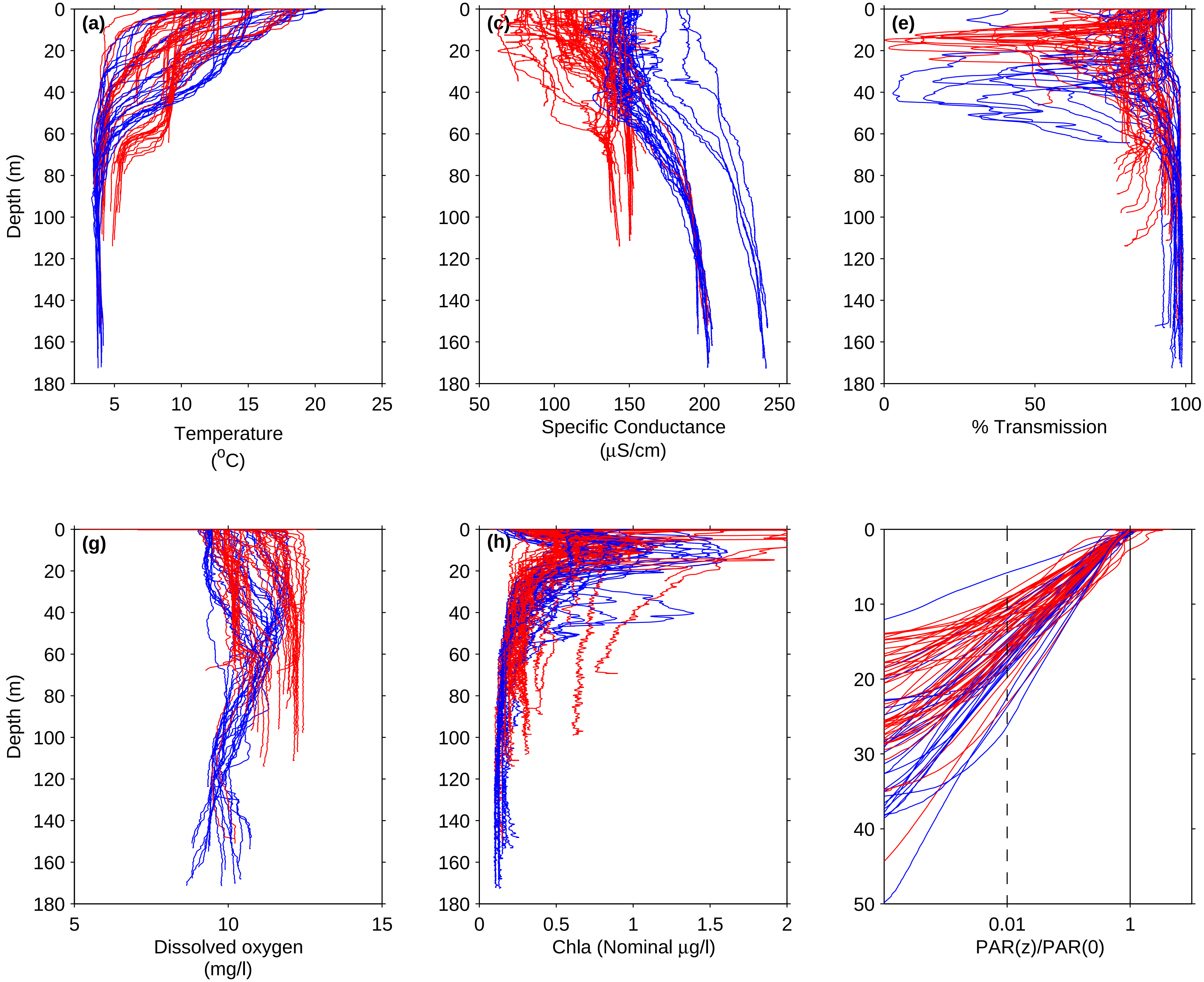
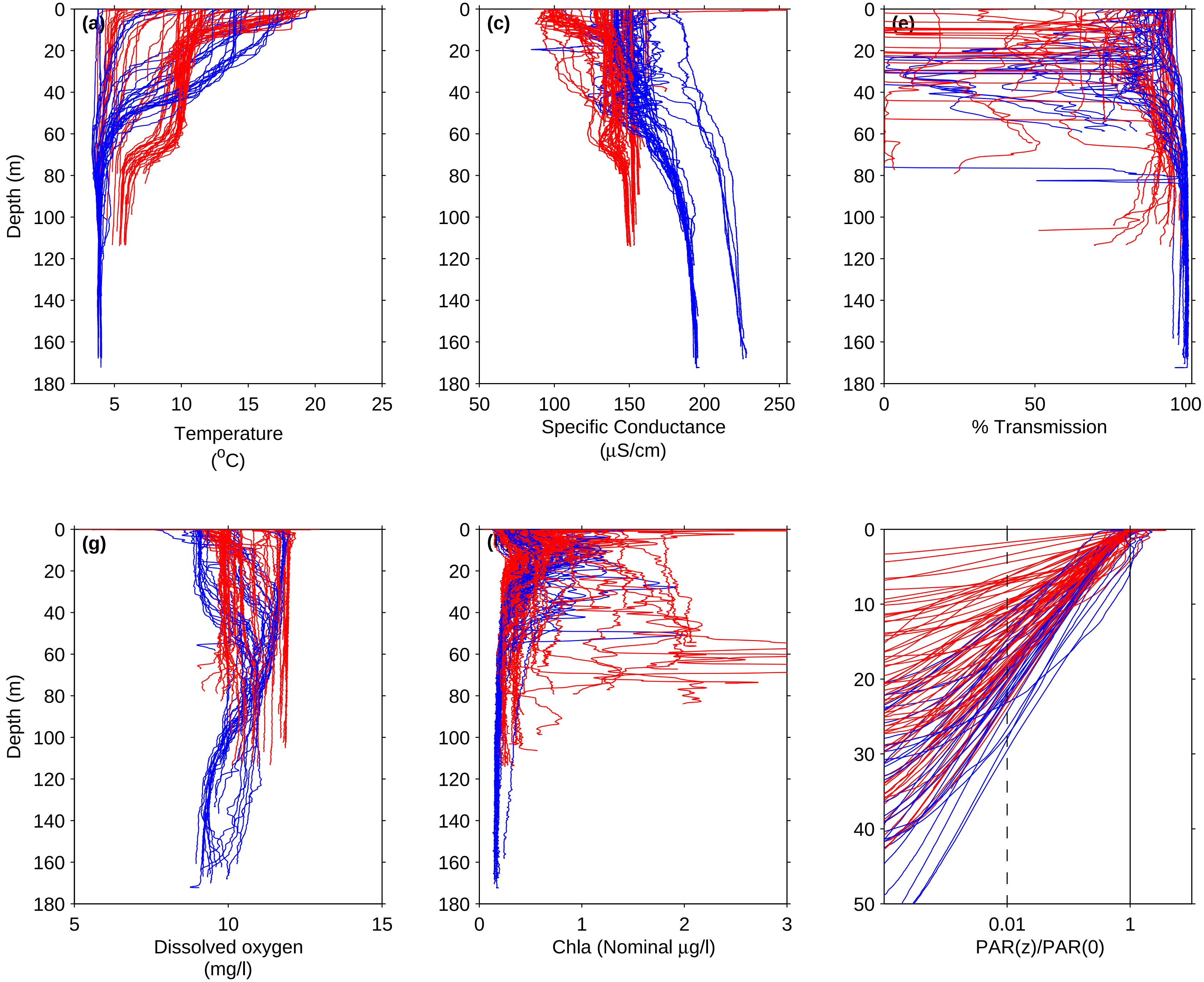


Figure F1.2 All Kinbasket (BLU) and Revesltoke (RED) Data, 2015



Appendix 1
Station Names

Name*	Description	Approximate Location
Kinbasket-Columbia Arm		
K1fb	**Forebay**	52°05.673 118°32.902
K1.5	Kin-PP	52°06.889 118°30.501
K2mi	**Middle**	52°07.858 118°26.363
K2.1	Kin-Mouth of Columbia to Kinbasket	52°06.044 118°24.264
K2.4	10 km from mouth of Columbia	52°03.246 118°16.766
K2.8	20 km from mouth of Columbia	52°00.219 118°09.401
K3co	**Columbia Reach**	51°58.438 118°05.030
K3.1	30 km from mouth of Columbia	51°57.067 118°02.334
K3.5	40 km from mouth of Columbia	51°53.595 117°55.577
K3.7	50 km from mouth of Columbia	51°50.381 117°48.576
K4	60 km from mouth of Columbia	51°47.010 117°41.750
Kinbasket-Wood Arm		
Kwo0	Mouth of Wood to Kinbasket	52°09.004 118°22.994
Kwo1	**Wood Arm**	52°08.269 118°18.024
Kwo2	End of Wood Arm	52°10.738 118°10.020
Kinbasket-Canoe Arm		
Kca0	Mouth of Canoe to Kinbasket	52°10.631 118°27.049
Kca1	**Canoe Reach**	52°12.547 118°28.516
Kca1.5	10 km from mouth of Canoe	52°15.509 118°31.235
Kca2.5	20 km from mouth of Canoe	52°20.025 118°35.804
Kca3	30 km from mouth of Canoe	52°24.198 118°41.857
Kca4	40 km from mouth of Canoe	52°28.714 118°46.355
Kca5	50 km from mouth of Canoe	52°33.452 118°50.709

Name*	**Description**	**Approximate Location**
Revelstoke		
R1fbbm	Rev-Forebay by log boom mooring	51°03.222 118°11.383
R1prof	Rev-Forebay by profiler mooring	51°04.037 118°10.937
R1sub	Rev-Forebay by subsurface mooring	51°04.272 118°10.919
R1fb	**Rev-Forebay**	51°04.584 118°10.929
R1.04	Rev-2 km from Forebay	51°05.670 118°11.000
R1.08	Rev-4 km from Forebay	51°06.743 118°11.544
R1.12	Rev-6km from Forebay	51°07.756 118°11.886
R1.16	Rev-8km from Forebay	51°08.774 118°12.730
R1.2	Rev-10 km from Forebay	51°09.988 118°12.677
R1.24	Rev-12 km from Forebay	51°10.934 118°12.533
R1.28	Rev-14 km from Forebay	51°12.052 118°12.682
R1.32	Rev-16 km from Forebay	51°13.085 118°13.249
R1.36	Rev-18 km from Forebay	51°14.142 118°13.685
R1.39spar	Rev-Laforme spar	51°14.667 118°14.054
R1.39prof	Rev-Laforme profiler	51°14.832 118°14.258
R1.4	Rev-20 km from Forebay	51°15.179 118°14.332
R1.44	Rev-22 km from Forebay	51°16.131 118°15.288
R1.5	Rev-25 km from Forebay	51°17.785 118°17.476
R1.6	Rev-30 km from Forebay	51°19.593 118°20.842
R1.7	Rev-35 km from Forebay	51°21.467 118°24.153
R1.9	Rev-40 km from Forebay	51°23.852 118°26.552
R2miprof	Rev-Middle Profiler	51°25.931 118°26.597
R2misub	Rev-Mid sub	51°25.981 118°27.675
R2mi	**Rev-Mid**	51°26.612 118°27.939
Rd0	Rev-Downie loop across from boat launch	51°27.929 118°27.109
Rd1	Rev-Downie Loop 3.35 km from BL site	51°29.063 118°25.003
R2.1	Rev-50 km from Forebay	51°29.082 118°29.093
R2.5	Rev-60 km from Forebay	51°33.778 118°33.541
R2.7	Rev-70 km from Forebay	51°38.586 118°37.338
R3up	**Rev-Upper**	51°43.891 118°39.633

* Main stations are bold

Appendix 2
List of Profiles

Appendix 2 List of Profiles, 2014

Cast Number	Date	Site Name	Time On	Time Off	GPS	Depth (m)	Stn
1	21/May/2014	Rev - Middle	8:44	8:53	51°26.616 118°28.121	80	R2mi
2	21/May/2014	Rev - Upper	10:31	10:37	51°43.770 118°39.615	35	R3up
3	21/May/2014	Rev - Downie Loop Across from Boat Launch	11:57	12:06	51°27.901 118°27.171	70	Rd0
4	21/May/2014	Rev - Downie Loop 3.35km from BL Site	12:13	12:18	51°29.046 118°25.021	40	Rd1
5	21/May/2014	Rev - Forebay	1:18	1:28	51°04.497 118°10.963	100	R1fb
6	03/Jun/2014	Kin - Canoe	10:25	10:36	52°12.418 118°28.463	105	Kca1
7	03/Jun/2014	Kin - Wood	11:54	12:00	52°08.282 118°18.715	45	Kwo1
8	03/Jun/2014	Kin - Center	12:49	1:02	52°07.870 118°26.390	125	K2mi
9	03/Jun/2014	Kin - Forebay	1:37	1:52	52°05.646 118°32.897	155	K1fb
10	04/Jun/2014	Kin - Columbia	7:41	7:57	51°57.988 118°04.876	155	K3co
11	11/Jun/2014	Rev - Forebay	8:01	8:14	51°04.540 118°10.917	115	R1fb
12	11/Jun/2014	Rev - 10km from forebay	8:29	8:39	51°09.830 118°12.735	110	R1.2
13	11/Jun/2014	Rev - 20km from forebay	8:53	9:04	51°15.164 118°14.357	100	R1.4
14	11/Jun/2014	Rev - 30km from forebay	9:19	9:28	51°19.560 118°20.736	87	R1.6
15	11/Jun/2014	Rev - 40km from forebay	9:44	9:54	51°23.694 118°26.574	87	R1.9
16	11/Jun/2014	Rev - Middle	10:04	10:12	51°26.628 118°28,086	75	R2mi
17	11/Jun/2014	Rev - Downie Loop Across from Boat Launch	10:19	10:27	51°27.946 118°27.116	67	Rd0
18	11/Jun/2014	Rev - Downie Loop 3.35km from BL Site	10:34	10:39	51°29.086 118°24.997	25	Rd1
19	11/Jun/2014	Rev - 50km from forebay	10:51	10:59	51°29.056 118°29.087	63	R2.1
20	11/Jun/2014	Rev - 60km from forebay	11:20	11:27	51°33.730 118°33.494	55	R2.5
21	11/Jun/2014	Rev - 70km from forebay	11:41	11:48	51°38.591 118°37.266	47	R2.7
22	11/Jun/2014	Rev - Upper	12:03	12:09	51°43.866 118°39.639	39	R3up
23	16/Jun/2014	Kin - Canoe	10:14	10:26	52°12.507 118°28.495	110	Kca1
24	16/Jun/2014	Kin - Wood	11:48	11:55	52°08.268 118°18.682	50	Kwo1
25	16/Jun/2014	Kin - Center	12:55	1:10	52°07.853 118°26.423	150	K2mi
26	16/Jun/2014	Kin - Forebay	1:24	1:40	52°05.640 118° 32. 887	163	K1fb
27	17/Jun/2014	Kin - Columbia	7:44	7:59	51°57.980 118°04.896	155	K3co
28	23/Jun/2014	Rev - Middle	9:01	9:10	51°26.690 118°28.107	80	R2mi
29	23/Jun/2014	Rev - Upper	10:47	10:53	51°43.775 118°39.617	35	R3up
30	23/Jun/2014	Rev - Downie Loop Across from Boat Launch	12:17	12:25	51°27.909 118°27.179	65	Rd0
31	23/Jun/2014	Rev - Downie Loop 3.35km from BL Site	12:33	12:38	51°29.070 118°24.982	38	Rd1
32	24/Jun/2014	Rev - Forebay & PP	7:50	8:02	51°04.429 118°10.945	113	R1fb
33	25/Jun/2014	Rev - Kin PP	7:22	7:37	52°06.870 118°30.128	155	R1.5
34	26/Jun/2014	Rev - Middle PP	7:42	7:51	51°26.695 118°28.122	80	R2mi
35	14/Jul/2014	Kin - Canoe	10:57	11:08	52°12.488 118°28.455	110	Kca1
36	14/Jul/2014	Kin - Wood	12:26	12:33	52°08.268 118°18.628	60	Kwo1
37	14/Jul/2014	Kin - Center	1:36	1:51	52°07.832 118°26.417	155	K2mi
38	14/Jul/2014	Kin - Forebay	2:08	2:26	52°05.683 118°32.913	170	K1fb
39	15/Jul/2014	Kin - Columbia	7:40	7:57	51°57.950 118°04.828	165	K3co
40	21/Jul/2014	Rev - Middle	8:37	8:46	51°26.654 118°28.139	80	R2mi
41	11/Aug/2014	Kin - Canoe	10:12	10:24	52°12.481 118°28.450	115	Kca1
42	11/Aug/2014	Kin - Wood	11:46	11:54	52°08.258 118°18.640	65	Kwo1
43	11/Aug/2014	Kin - Center	12:56	1:13	52°07.860 118°26.412	163	K2mi
44	11/Aug/2014	Kin - Forebay	1:26	1:44	52°05.648 118°32.888	175	K1fb
45	12/Aug/2014	Kin - Columbia	7:39	7:56	51°57.975 118°04.867	175	K3co
46	18/Aug/2014	Rev - Middle	8:37	8:46	51°26.663 118°28.101	80	R2mi
47	18/Aug/2014	Rev - Upper	10:17	10:22	51°43.789 118°39.631	35	R3up
48	18/Aug/2014	Rev - Downie Loop Across from Boat Launch	11:49	11:57	51°27.890 118°27.219	69	Rd0
49	18/Aug/2014	Rev - Downie Loop 3.35km from BL Site	12:03	12:08	51°29.051 118°25.020	38	Rd1
50	19/Aug/2014	Rev - Forebay & PP	7:49	8:00	51°04.474 118°10.915	105	R1fb
51	20/Aug/2014	Kin - PP	7:38	7:54	52°06.888 118°30.112	155	R1.5

52	21/Aug/2014	Rev - Middle PP	7:43	7:51	51°26.694 118°28.116	75	R2mi
53	15/Sep/2014	Kin - Canoe	10:32	10:44	52°12.438 118°28.472	115	Kca1
54	15/Sep/2014	Kin - Wood	12:10	12:18	52°08.289 118°18.683	65	Kwo1
55	15/Sep/2014	Kin - Center	1:19	1:34	52°07.823 118°26.441	150	K2mi
56	15/Sep/2014	Kin - Forebay	1:48	2:05	52°05.661 118°32.914	175	K1fb
57	16/Sep/2014	Kin - Columbia	7:50	8:07	51°57.940 118°04.807	170	K3co
58	22/Sep/2014	Rev - Middle	8:36	8:44	51°26.698 118°28.066	75	R2mi
59	22/Sep/2014	Rev - Upper	10:21	10:26	51°43.800 118°39.643	35	R3up
60	22/Sep/2014	Rev - Downie Loop Across from Boat Launch	11:55	12:03	51°27.892 118°27.214	70	Rd0
61	22/Sep/2014	Rev - Downie Loop 3.35km from BL Site	12:10	12:16	51°29.061 118°25.002	40	Rd1
62	23/Sep/2014	Rev - Forebay & PP	7:57	8:09	51°04.453 118°10.939	115	R1fb
63	24/Sep/2014	Kin - PP	7:21	7:38	52°06.870 118°30.142	170	K1.5
64	25/Sep/2014	Rev - Middle PP	7:25	7:34	51°26.687 118°28.116	75	R2mi
65	14/Oct/2014	Rev - Middle	11:24	11:33	51°26.656 118°28.150	80	R2mi
66	14/Oct/2014	Rev - 50km from forebay	12:31	12:39	51°29.061 118°29.107	65	R2.1
67	14/Oct/2014	Rev - 60km from forebay	12:52	12:59	51°33.719 118°33.468	55	R2.5
68	14/Oct/2014	Rev - 70km from forebay	1:12	1:18	51°38.579 118°37.262	47	R2.7
69	14/Oct/2014	Rev - Upper	1:31	1:37	51°43.760 118°39.566	35	R3up
70	14/Oct/2014	Rev - Downie Loop Across from Boat Launch	2:59	3:07	51°27.929 118°27.109	70	Rd0
71	14/Oct/2014	Rev - Downie Loop 3.35km from BL Site	3:13	3:19	51°29.063 118°25.003	71	Rd1
72	15/Oct/2014	Rev - Forebay	8:50	9:02	51°04.460 118°10.928	115	R1fb
73	15/Oct/2014	Rev - 10km from forebay	10:20	10:31	51°09.808 118°12.728	110	R1.2
74	15/Oct/2014	Rev - 20km from forebay	10:45	10:56	51°15.171 118°14.386	100	R1.4
75	15/Oct/2014	Rev - 30km from forebay	11:13	11:23	51°19.533 118°20.683	85	R1.6
76	15/Oct/2014	Rev - 40km from forebay	11:38	11:48	51°23.733 118°26.556	90	R1.9
77	15/Oct/2014	Rev - 120m downstream from Rev Mid Profiler	11:56	12:05	51°25.828 118°27.605	78	R2miprof
78	20/Oct/2014	Kin - Canoe	10:26	10:39	52°12.432 118°28.463	115	Kca1
79	20/Oct/2014	Kin - Wood	12:22	12:29	52°08.285 118°18.685	55	Kwo1

Appendix 2 List of Profiles, 2015

Cast No.	Date	Site Name	Time On	Time Off	GPS	Depth (m)	Stn
1	09/Apr/2015	Between Martha Crk and Laforme Crk Test run	9:34	9:43	51˚11.910 118˚12.384	85	R1.28
2	13/Apr/2015	Kin - Canoe	10:20	10:31	52˚12.397 118˚28.450	149	Kca1
3	13/Apr/2015	Kin - Wood	12:22	12:29	52˚08.294 118˚18.858	59	Kwo1
4	13/Apr/2015	Kin - Forebay	1:59	2:15	52˚05.623 118˚32.992	175	K1fb
5	21/Apr/2015	Rev - Forebay	7:47	7:59	51˚04.484 118˚10.950	124	R1fb
6	21/Apr/2015	Rev - 10km from Forebay	9:17	9:28	51˚09.840 118˚12.730	111	R1.2
7	21/Apr/2015	Rev - 20km from Forebay	9:42	9:53	51˚15.164 118˚14.355	111	R1.4
8	21/Apr/2015	Rev - 30km from Forebay	10:10	10:20	51˚19.546 118˚20.696	95	R1.6
9	21/Apr/2015	Rev - 40km from Forebay	10:34	10:43	51˚23.714 118˚26.568	96	R1.9
10	21/Apr/2015	Rev - Middle	10:53	11:02	51˚26.634 118˚28.102	88-83	R2mi
11	21/Apr/2015	Rev - Downie Loops Across from Boat Launch	12:00	12:07	51˚27.909 118˚27.144	75-72	Rd0
12	21/Apr/2015	Rev - Downie Loop 3.35km from BL site	12:14	12:20	51˚29.049 118˚25.010	46	Rd1
13	21/Apr/2015	Rev - 50km from Forebay	12:30	12:38	51˚29.024 118˚29.060	70	R2.1
14	21/Apr/2015	Rev - 60km from Forebay	12:53	1:00	51˚33.703 118˚33.473	60	R2.5
15	21/Apr/2015	Rev - 70km from Forebay	1:18	1:24	51˚38.542 118˚37.261	42	R2.7
16	21/Apr/2015	Rev - Upper	1:41	1:46	51˚43.755 118˚39.591	41	R3up
17	27/Apr/2015	Rev - Forebay	8:56	9:08	51˚04.473 118˚10.908	124-110	R1fb
18	27/Apr/2015	Rev - 10km from Forebay	9:33	9:42	51˚09.781 118˚12.711	111	R1.2
19	11/May/2015	Kin - Canoe	10:27	10:38	52˚12.406 118˚28.457	147	Kca1
20	11/May/2015	Kin - Wood	12:02	12:09	52˚08.296 118˚18.778	55	Kwo1
21	11/May/2015	Kin - Center	1:10	1:23	52˚07.835 118˚26.385	158	K2mi
22	11/May/2015	Kin - Forebay	1:39	1:55	52˚05.678 118˚32.879	169	K1fb
23	12/May/2015	Kin - Columbia	7:52	8:08	51˚57.979 118˚04.846	168	K3co
24	19/May/2015	Rev - Middle	8:51	9:00	51˚26.673 118˚28.119	88-84	R2mi
25	19/May/2015	Rev - Upper	10:34	10:39	51˚43.743 118˚39.623	41	R3up
26	19/May/2015	Rev - Downie Loop Across from Boat Launch	12:06	12:15	51˚27.887 118˚27.238	75-72	Rd0
27	19/May/2015	Rev - Downie Loops 3.35km from BL site	12:22	12:27	51˚29.067 118˚24.981	42-40	Rd1
28	20/May/2015	Rev - Forebay	7:49	8:00	51˚04.287 118˚10.942	125-115	R1fb
29	15/Jun/2015	Kin - Canoe	10:15	10:29	52˚12.424 118˚28.457	156	Kca1
30	15/Jun/2015	Kin - Wood	11:50	11:57	52˚08.279 118˚18.710	65	Kwo1
31	15/Jun/2015	Kin - Center	1:04	1:18	52˚07.842 118˚26.431	166	K2mi
32	15/Jun/2015	Kin - Forebay	1:32	1:49	52˚05.652 118˚32.937	180	K1fb
33	16/Jun/2015	Kin - Columbia Garbage	7:42	7:44	N/A	NaN	N/A
34	16/Jun/2015	Kin - Columbia	7:45	8:01	51˚57.945 118˚04.819	177	K3co
35	22/Jun/2015	Rev - Middle	8:36	8:45	51˚26.685 118˚28.116	85	R2mi
36	22/Jun/2015	Rev - Upper	10:14	10:20	51˚43.750 118˚39.597	41	R3up
37	22/Jun/2015	Rev - Downie Loop Across from Boat Launch	11:49	11:57	51˚27.872 118˚27.230	73	Rd0
38	22/Jun/2015	Rev - Downie Loop 3.35km from BL site	12:02	12:08	51˚29.038 118˚25.031	45	Rd1
39	23/Jun/2015	Rev - Forebay & PP	7:54	8:06	51˚04.496 118˚10.933	124	R1fb
40	24/Jun/2015	Kin - PP	7:15	7:32	52˚06.889 118˚30.093	175	K1.5
41	25/Jun/2015	Rev - Middle PP	7:33	7:41	51˚26.681 118˚28.120	85	R2mi
42	13/Jul/2015	Kin - Canoe	10:09	10:21	52˚12.376 118˚28.462	158	Kca1
43	13/Jul/2015	Kin - Wood	10:46	10:53	52˚08.271 118˚18.701	68	Kwo1
44	13/Jul/2015	Kin - Forebay	12:15	12:32	52˚05.636 118˚32.982	184	K1fb
45	14/Jul/2015	Kin - Columbia	7:35	7:52	51˚57.982 118˚04.890	181	K3co
46	14/Jul/2015	Kin - Canoe	9:41	9:53	52˚12.456 118˚28.480	158	Kca1
47	20/Jul/2015	Rev - Middle	8:31	8:40	51˚26.695 118˚28.135	85	R2mi
48	20/Jul/2015	Rev - Upper	10:10	10:16	51˚43.759 118˚39.601	41	R3up
49	20/Jul/2015	Rev - Downie Loop Across from Boat Launch	11:39	11:47	51˚27.893 118˚27.221	74	Rd0
50	20/Jul/2015	Rev - Downie Loop 3.35km from BL site	11:53	11:58	51˚29.040 118˚25.027	45	Rd1
51	22/Jul/2015	Rev - Forebay & PP	8:10	8:22	51˚04.456 118˚10.936	123	R1fb
52	23/Jul/2015	Kin - PP	7:30	7:47	52˚06.850 118˚30.138	173	K1.5
53	24/Jul/2015	Rev - Middle PP	7:20	7:30	51˚26.660 118˚28.125	85	R2mi
54	12/Aug/2015	Rev - 10km from Forebay	8:38	8:48	51˚09.787 118˚12.742	109	R1.2
55	12/Aug/2015	Rev - 20km from Forebay	9:03	9:13	51˚15.132 118˚14.343	106	R1.4
56	12/Aug/2015	Rev - 30km from Forebay	9:28	9:38	51˚19.535 118˚20.684	93	R1.6
57	12/Aug/2015	Rev - 40km from Forebay	9:52	10:01	51˚23.660 118˚26.477	84	R1.9
58	12/Aug/2015	Rev - Middle	10:11	10:20	51˚26.572 118˚28.107	87	R2mi

Appendix 2 List of Profiles, 2015

59	12/Aug/2015	Rev - 50km from Forebay	10:29	10:35	51˚28.984 118˚29.052	60	R2.1
60	12/Aug/2015	Rev - 60km from Forebay	10:50	10:58	51˚33.656 118˚33.426	63	R2.5
61	12/Aug/2015	Rev - 70km from Forebay	11:11	11:17	51˚38.523 118˚37.262	43	R2.7
62	12/Aug/2015	Rev - Upper	11:32	11:37	51˚43.761 118˚39.610	41	R3up
63	12/Aug/2015	Rev - Downie Loop Across from Boat Launch	12:16	12:25	51˚27.901 118˚27.205	73	Rd0
64	12/Aug/2015	Rev - Downie Loop 3.35km from BL site	12:31	12:37	51˚29.070 118˚24.976	45	Rd1
65	12/Aug/2015	Rev - Forebay	1:34	1:46	51˚04.480 118˚10.971	123	R1fb
66	23/Aug/2015	Kin - Canoe	9:58	10:09	52˚12.417 118˚28.461	158	Kca1
67	23/Aug/2015	Kin - Wood	11:32	11:39	52˚08.288 118˚18.824	66	Kwo1
68	23/Aug/2015	Kin - Center	12:40	12:55	52˚07.830 118˚26.481	164	K2mi
69	23/Aug/2015	Kin - Forebay	1:08	1:25	52˚05.615 118˚32.958	181-177	K1fb
70	24/Aug/2015	Kin - Columbia	7:42	7:59	51˚57.990 118˚04.892	179	K3co
71	24/Aug/2015	Rev - Forebay	12:23	12:35	51˚04.448 118˚10.943	121	R1fb
72	25/Aug/2015	Rev - Middle & PP	8:37	8:46	51˚26.662 118˚28.115	85	R2mi
73	25/Aug/2015	Rev - Upper	11:05	11:10	51˚43.772 118˚39.607	41	R3up
74	25/Aug/2015	Rev - Downie Loop Across from Boat Launch	12:37	12:45	51˚27.887 118˚27.189	73	Rd0
75	25/Aug/2015	Rev - Downie Loops 3.35km from BL site	12:51	12:57	51˚29.045 118˚25.017	45	Rd1
76	26/Aug/2015	Kin - PP	7:14	7:30	52˚06.861 118˚30.174	171	K1.5
77	27/Aug/2015	Rev - Forebay	7:32	7:44	51˚04.367 118˚10.991	120-110	R1fb
78	14/Sep/2015	Rev - Middle	11:23	11:33	51˚26.671 118˚28.141	88	R2mi
79	14/Sep/2015	Rev - Upper	1:04	1:10	51˚42.734 118˚39.570	41	R3up
80	14/Sep/2015	Rev - Downie Loop Across from Boat Launch	2:35	2:44	51˚27.895 118˚27.232	73	Rd0
81	14/Sep/2015	Rev - Downie Loop 3.35km from BL site	2:49	2:55	51˚29.050 118˚25.010	45	Rd1
82	15/Sep/2015	Rev - Forebay	7:54	8:05	51˚04.440 118˚10.920	121-113	R1fb
83	21/Sep/2015	Kin - Canoe	10:07	10:19	52˚12.424 118˚28.462	155	Kca1
84	21/Sep/2015	Kin - Wood	11:40	11:48	52˚08.319 118˚18.737	64	Kwo1
85	21/Sep/2015	Kin - Forebay	12:56	1:14	52˚05.651 118˚32.940	180	K1fb
86	22/Sep/2015	Kin - Columbia	9:14	9:31	51˚57.983 118˚04.880	177	K3co
87	22/Sep/2015	Kin - Center	11:43	11:56	52˚07.769 118˚26.420	165	K2mi
88	22/Sep/2015	Kin - PP	12:04	12:19	52˚06.782 118˚30.165	152	K1.5
89	23/Sep/2015	Rev - Middle PP	7:29	7:38	51˚26.693 118˚28.102	83	R2mi
90	24/Sep/2015	Rev - Forebay PP	7:44	7:57	51˚04.451 118˚10.936	122	R1fb
91	29/Sep/2015	Rev - Forebay	8:21	8:33	51˚04.429 118˚10.935	122	R1fb
92	29/Sep/2015	Rev - 10km from Forebay	8:48	8:57	51˚09.818 118˚12.739	101	R1.2
93	29/Sep/2015	Rev - 20km from Forebay	9:12	9:23	51˚15.174 118˚14.357	107	R1.4
94	29/Sep/2015	Rev - 30km from Forebay	9:38	9:47	51˚19.558 118˚20.706	93	R1.6
95	29/Sep/2015	Rev - 40km from Forebay	10:04	10:13	51˚23.714 118˚26.566	94-89	R1.9
96	29/Sep/2015	Rev - Middle	10:22	10:30	51˚26.629 118˚28.127	87	R2mi
97	29/Sep/2015	Rev - Downie Loop Across from Boat Launch	10:37	10:44	51˚27.897 118˚27.131	74	Rd0
98	29/Sep/2015	Rev - Downie Loop 3.35km from BL site	10:51	10:56	51˚29.098 118˚24.935	41	Rd1
99	29/Sep/2015	Rev - 50km from Forebay	11:08	11:15	51˚29.020 118˚29.084	60	R2.1
100	29/Sep/2015	Rev - 60km from Forebay	11:30	11:37	51˚33.666 118˚33.427	63	R2.5
101	29/Sep/2015	Rev - 70km from Forebay	11:52	11:57	51˚38.557 118˚37.252	43	R2.7
102	29/Sep/2015	Rev - Upper	12:12	12:18	51˚43.785 118˚39.568	44	R3up
103	13/Oct/2015	Kin - Forebay	10:26	10:42	52˚05.533 118˚33.110	181	K1fb
104	19/Oct/2015	Rev - Forebay	7:47	7:59	51˚04.457 118˚10.963	120-117	R1fb
105	20/Oct/2015	Rev - Middle	8:48	8:57	51˚26.697 118˚28.144	88	R2mi
106	20/Oct/2015	Rev - Upper	10:27	10:32	51˚43.750 118˚39.594	41	R3up
107	20/Oct/2015	Rev - Downie Loop Across from Boat Launch	11:58	12:05	51˚27.899 118˚27.175	72	Rd0
108	20/Oct/2015	Rev - Downie Loop 3.35km from BL site	12:11	12:17	51˚29.057 118˚24.990	45	Rd1

Appendix 3
Seabird pump operation

A pump on the Sea-Bird profiler draws water across the temperature sensor, and through the conductivity and dissolved oxygen sensors. Two parameters in the profiler control pump operation. The first is the minimum conductivity frequency. For ocean going vessels it is often hard to tell how much time it will take for the profiler to be lifted from the deck and lowered into the water. To avoid turning on early, the profiler waits for the conductivity to exceed a minimum value before starting the pump. This minimum is set by Sea-Bird to 3,320 Hz, corresponding to a conductivity of about 5,300 µS/cm. For use in freshwater (e.g. in Kinbasket and Revelstoke with a conductivity of 200 µS/cm), this parameter should be set to zero to ensure the pump turns on. If the pump does not turn on, the descent of the instrument will force water through the plumbing and data will still be collected, with slightly reduced vertical resolution. The sensors which are not in the pump path - PAR, fluorescence, OBS and light transmission - are not affected by pump operation.

After the Sea-Bird has been turned on and placed in the water to soak, there is a second delay before the pump begins, controlled by the pump delay setting, to allow air in the plumbing to escape from the bleed valve (pinhole). If the air does not escape before the pump turns on, the pump may not prime properly, and it may draw little or no water across the sensors. The pump will eventually prime, but this may occur well into the downcast.

In 2008 the minimum conductivity frequency was set to zero. However, in 2009, 2010 and 2011, after calibration of the instrument by Sea-Bird, the minimum conductivity frequency was set for ocean use, and the pump did not run. Nevertheless, most of the temperature and conductivity data collected was satisfactory as descent forced water through the plumbing.

To avoid this, the parameters controlling the pump should be checked before each cruise. It may also be necessary to increase the soak time and to clean the pump bleed valve more often. Under calm conditions, the functioning of the bleed valve can be checked by watching the flow of bubbles from the bleed valve during the soak time. If it is possible to reach the pump outlet, the flow from the pump can occasionally be felt to ensure proper operation. Alternatively, the momentary flow of water from the pump outlet can be observed as the profiler is lifted from the water at the end of the cast.

Appendix 4
Additional Profiles

Profiles collected during measurement of primary production in Kinbasket Reservoir, see Tables 2.1 and 2.2.

Figure A4−1a Kinbasket Reservoir, K1.5, 2014

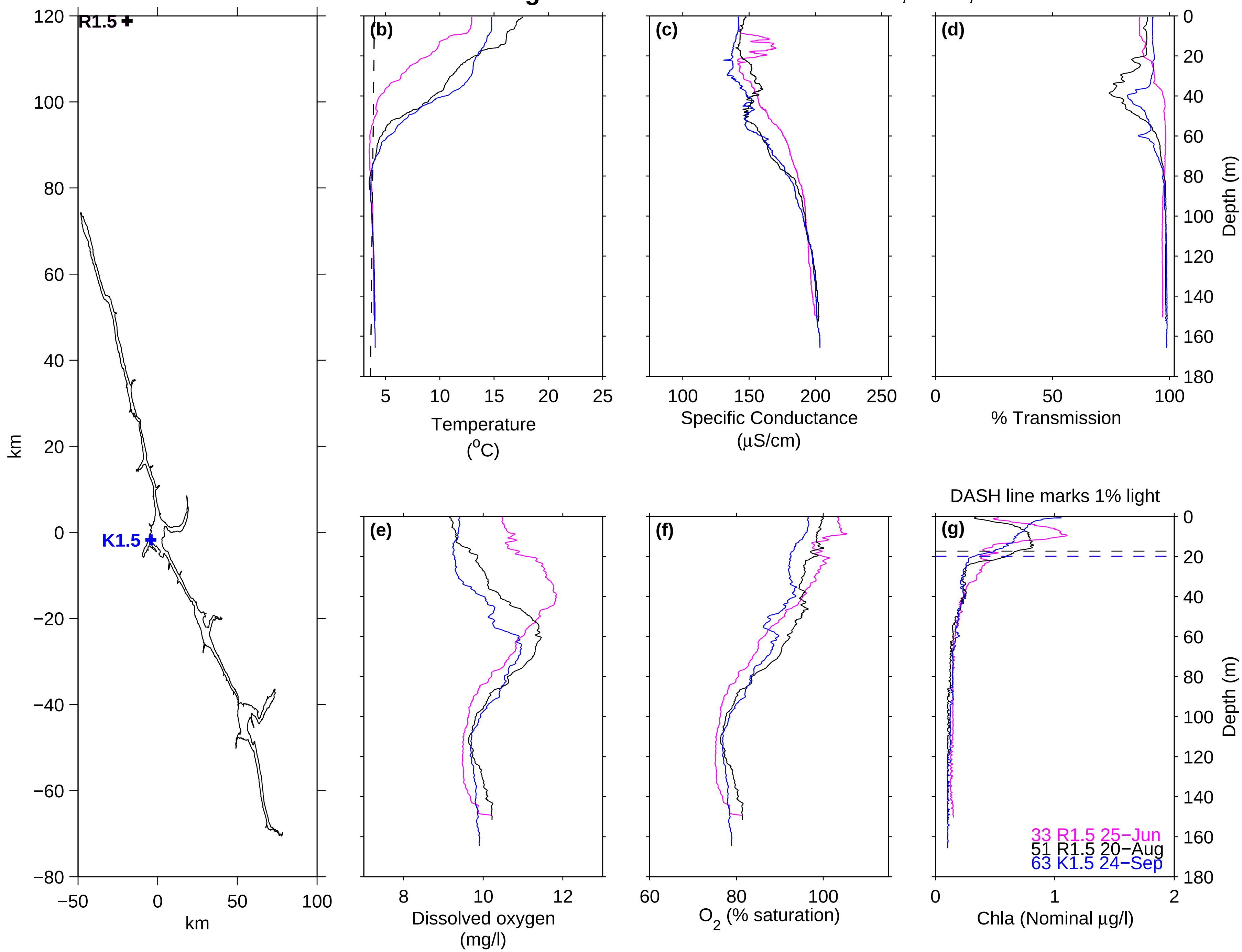
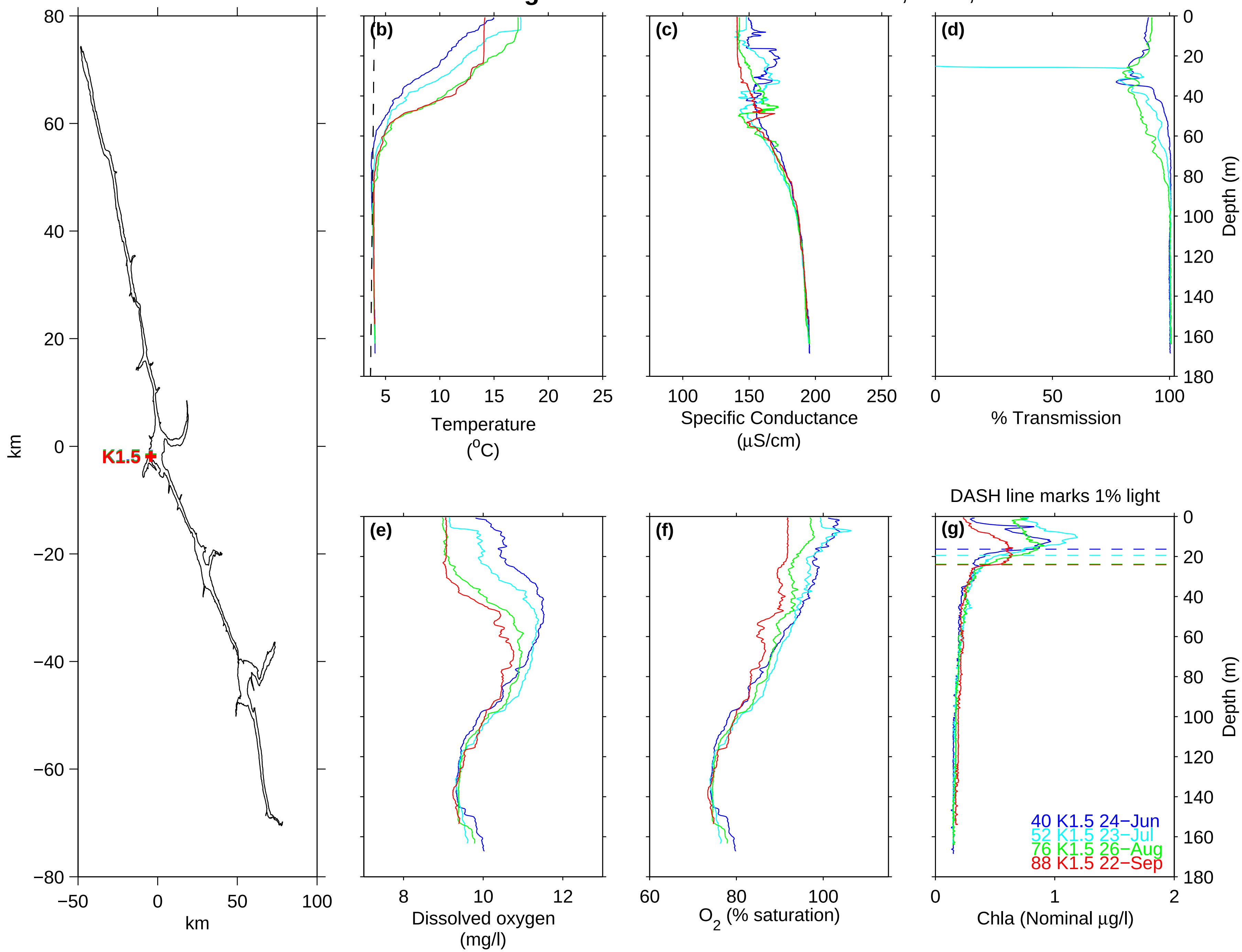


Figure A4−1b Kinbasket Reservoir, K1.5, 2015



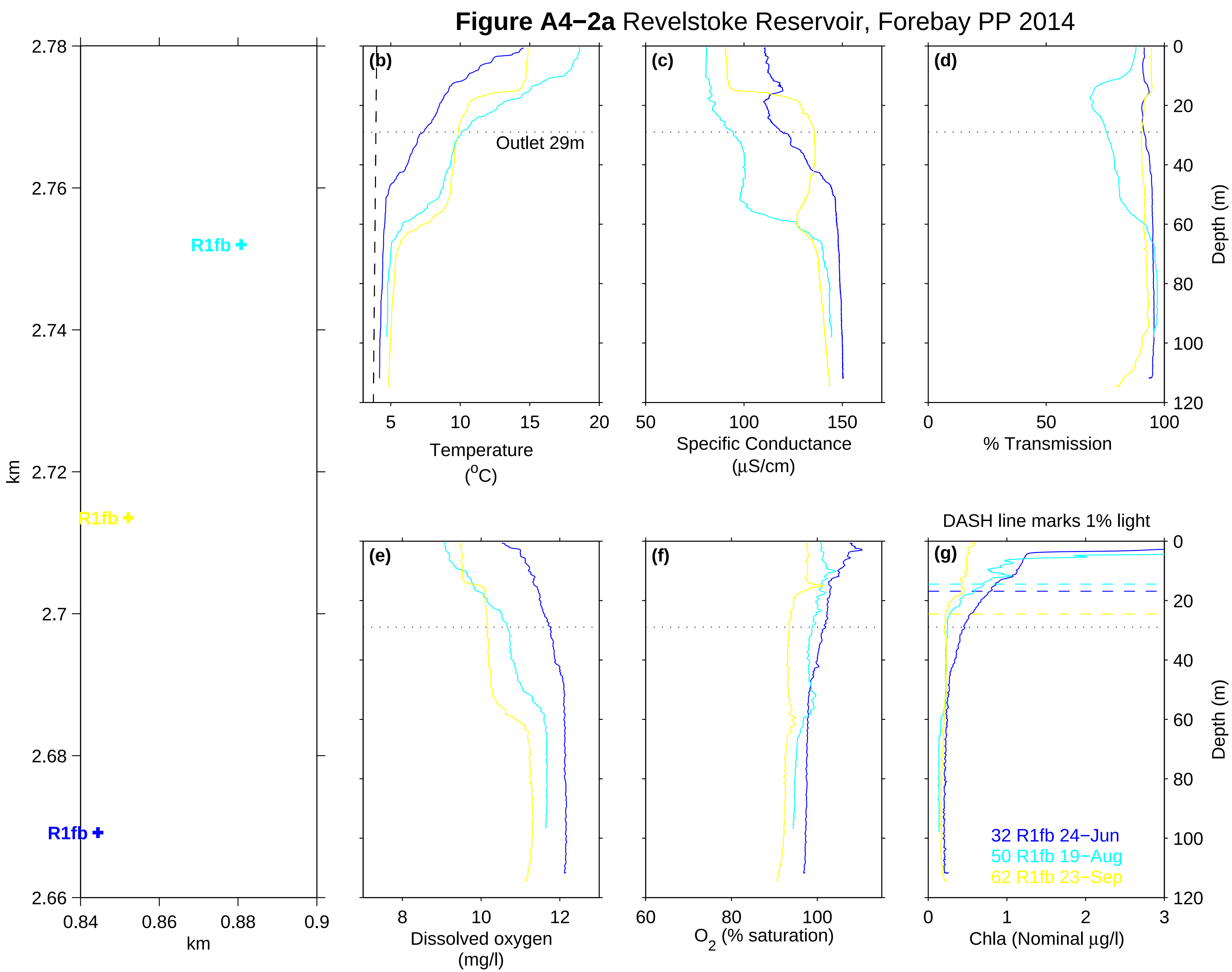
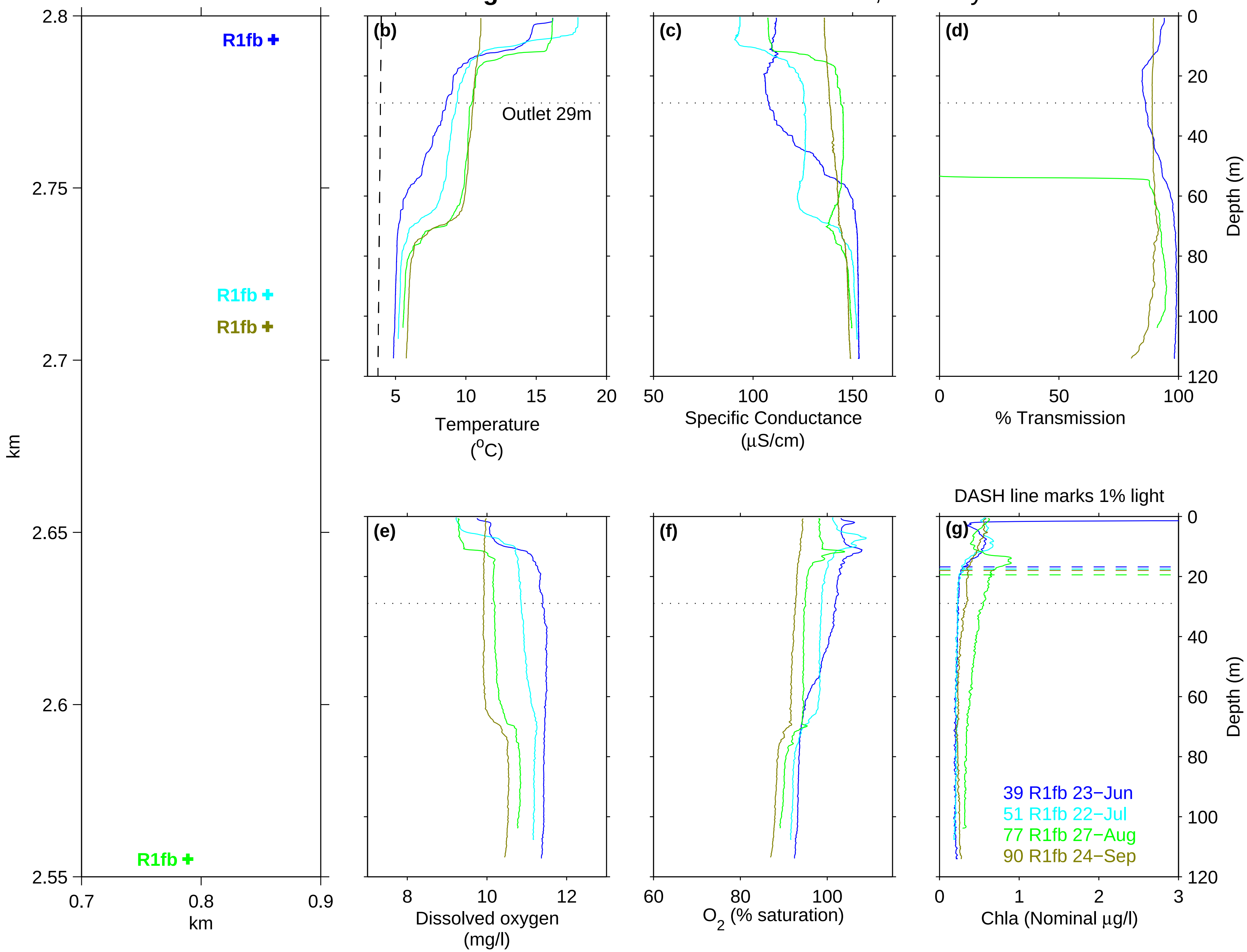


Figure A4−2a Revelstoke Reservoir, Forebay PP 2014
R1fb
R1fb
R1fb
km
km
(b)
Outlet 29m
Temperature (°C)
(c)
Specific Conductance (µS/cm)
(d)
% Transmission
Depth (m)
(e)
Dissolved oxygen (mg/l)
(f)
O2 (% saturation)
DASH line marks 1% light
(g)
Chla (Nominal µg/l)
Depth (m)
32 R1fb 24−Jun
50 R1fb 19−Aug
62 R1fb 23−Sep

Figure A4−2b Revelstoke Reservoir, Forebay PP 2015



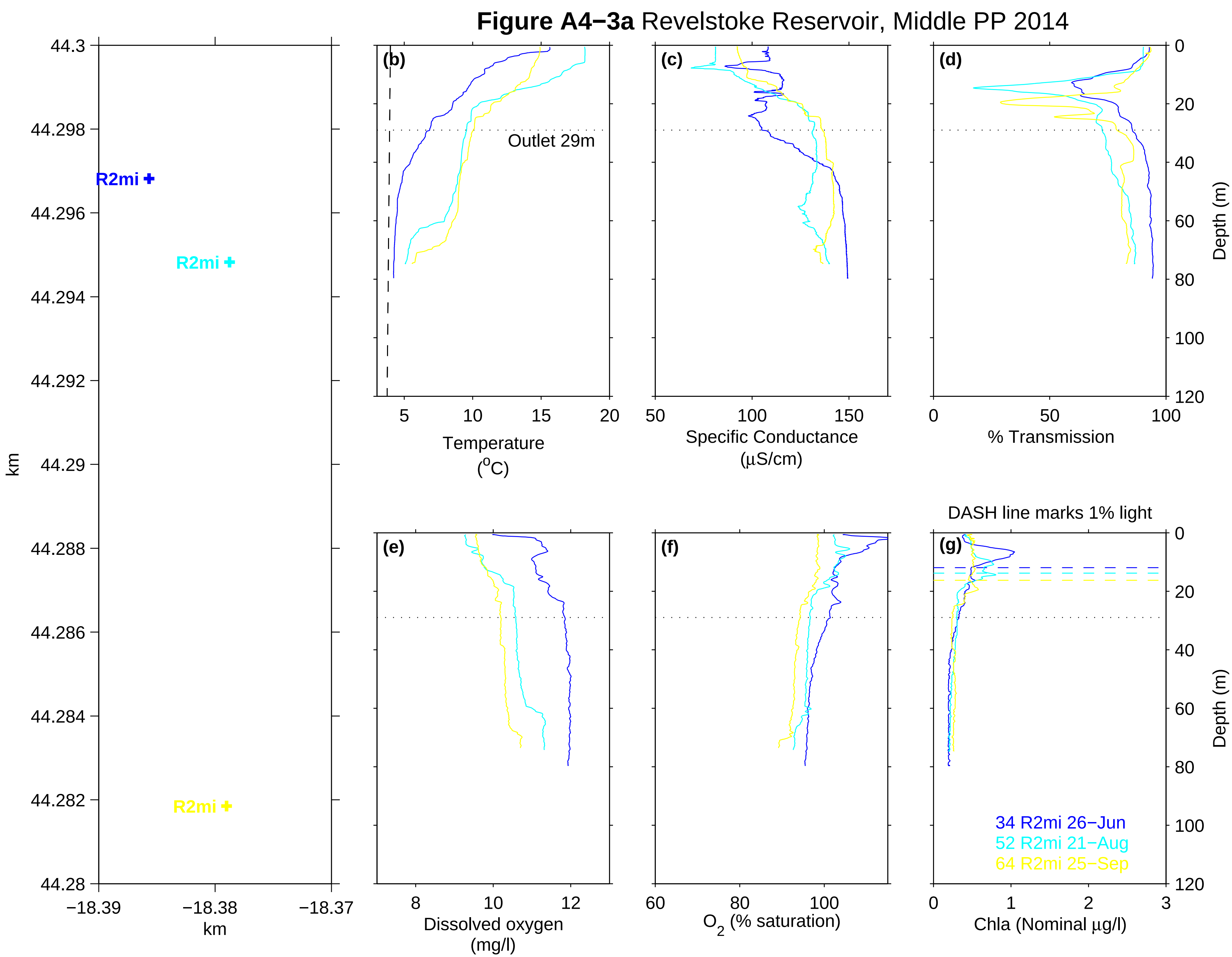
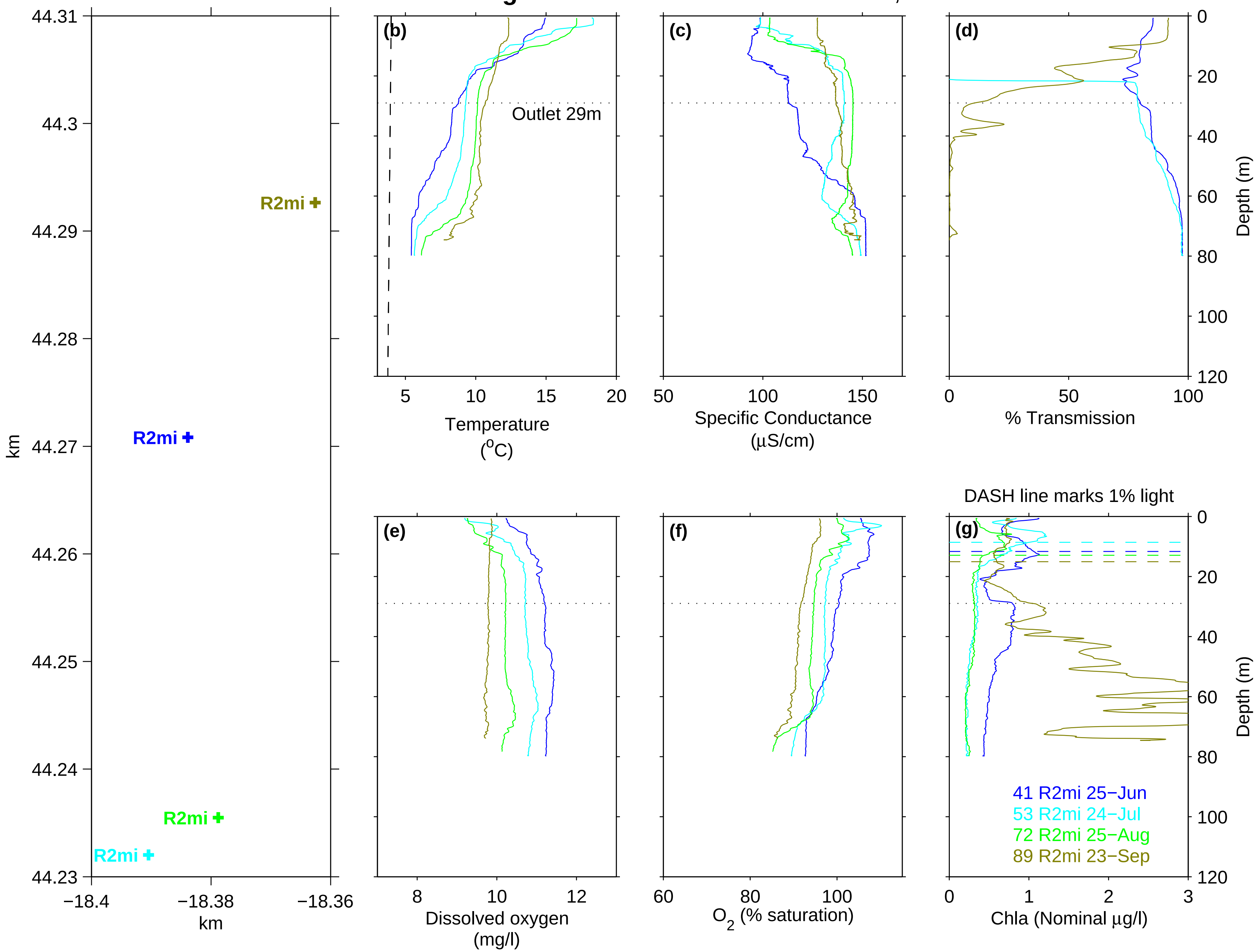


Figure A4−3a Revelstoke Reservoir, Middle PP 2014
R2mi
R2mi
R2mi
km
km
(b)
Outlet 29m
Temperature
(°C)
(c)
Specific Conductance
(µS/cm)
(d)
% Transmission
Depth (m)
DASH line marks 1% light
(e)
Dissolved oxygen
(mg/l)
(f)
O2 (% saturation)
(g)
Chla (Nominal µg/l)
Depth (m)
34 R2mi 26−Jun
52 R2mi 21−Aug
64 R2mi 25−Sep

Figure A4−3b Revelstoke Reservoir, Middle PP 2015



Appendix 4

Reservoir Water Chemistry
Kinbasket and Revelstoke Reservoirs, 2015

Karen Bray
BC Hydro

Reservoir Water Chemistry
Kinbasket and Revelstoke Reservoirs, 2015

High turbidity in Revelstoke Reservoir following major rain event, 2015

Prepared By:
Karen Bray
Revelstoke, B.C.

November 2016

Table of Contents

List of Figures

List of Tables

1. Introduction

This report summarises Year 8 (2015) water chemistry information from Kinbasket and Revelstoke reservoirs sampling. These results are a component of the study CLBMON-3 Kinbasket and Revelstoke Reservoirs Ecological Productivity conducted under the Columbia Water Use Plan.

2. Methods

Water samples were collected at four stations in Kinbasket reservoir and three stations in Revelstoke reservoir (Table 2, Figure 1). In 2015, sampling began in April at all stations except for Kinbasket Columbia Reach due to poor weather and unsafe conditions. Inclement weather was also responsible for the loss of October sessions at Kinbasket Canoe, Wood, and Columbia Reach stations.

Five litre Niskin bottles were lowered by cable in series to collect discrete depth samples at 2, 5, 10, 15, 20, 40, 60 and 80 m. A sample at 5 m above bottom was collected at all stations except for REV Upper and for some months in Kinbasket Wood when the site is <65 m depth. A 20 m tube with inside diameter of 2.54 cm was used to obtain a 0-20 m integrated depth sample for analysis of silica (Si) and chlorophyll *a* at each station. Only samples for TDP and SRP were field filtered and all samples were kept cold and packed on ice for shipping to the Maxxam Analytics Laboratory (Burnaby) for analyses. In previous project years samples were analysed at the Cultus Lake laboratory; however, in 2013 a change was made to Maxxam Analytics as Cultus Lake was no longer able to process samples.

Discrete depth samples were analysed for nitrite+nitrate (NO_2+NO_3, NN), total phosphorus (TP), total dissolved phosphorus (TDP), soluble reactive phosphorus (SRP), alkalinity, conductivity, pH, and turbidity. Integrated tube samples were analysed for soluble reactive silica. A summary of sample preparation, analytical methods, and laboratory detection limits can be found in Appendix 2 (Tributary Water Chemistry).

Note that all alkalinity samples done previously by Cultus Lake were treated as from low alkalinity sources and therefore titrated with additional acid to a pH 4.2 endpoint. This method returned roughly double mg$CaCO_3$/L values, and therefore, results from 2008-2012 have been adjusted to reflect a standard titration to 4.5 pH as per standard analytical methods (APHA 2012). Results for TP, TDP, and other parameters may be adjusted in future reports if analytical method differences are found between labs. The ratio of NO_2+NO_3 to TDP is no longer calculated as TDP values are almost uniformly near the detection limit of 2 µg/L. All results reported at less than detection limits are transformed to the detection limit for analysis and display purposes.

Secchi disk readings were taken at each site using a standard 20cm Secchi disk. The disk was lowered on the shady side of the boat to a depth where it could no longer be seen by the naked eye (i.e., no sunglasses) and then raised to where it became visible; the two depths were averaged to arrive at the final reading.

Table 1. Summary of reservoir station coordinates, maximum sampled depths, and survey dates, 2015.

Station	Coordinates	Max Depth Sampled (m)	Dates Sampled in 2015
KIN Forebay	52°05.611 118°32.932	175	April 13, May 11, June 15, July 13, Aug 23, Sep 21, Oct 13
KIN Canoe Reach	52°12.400 118°28.417	115	April 13, May 11, June 15, July 14, Aug 23, Sep 21
KIN Wood Arm	52°08.314 118°18.637	60	April 13, May 11, June 15, July 13, Aug 23, Sep 21
KIN Columbia Reach	51°58.448 118°05.061	170	May 12, June 16, July 14, Aug 24, Sep 22
REV Forebay	51°04.504 118°10.981	115	April 21, May 20, June 23, July 22, Aug 24, Sep 15, Oct 19
REV Middle	51°26.495 118°28.116	80	April 21, May 19, June 22, July 20, Aug 25, Sep 14, Oct 20
REV Upper	51°43.797 118°39.579	35	April 21, May 19, June 22, July 20, Aug 25, Sep 14, Oct 20

3. Results

Stations were sampled at Kinbasket reservoir forebay elevations between 740.5 m and 750.8 m; full pool is 754.4m and minimum level is 707.1 m (cf. Figure 2 of main report). The reservoir reached its minimum level (736.9 m) for the year on April 15, 2015, and its maximum level (750.9 m) on July 16, 2015. The total range of elevation in 2015 was 13.9 m whereas the maximum licenced range is 47 m without surcharge. In 2015, the minimum elevation was the highest and the change in reservoir elevation was the smallest since 1977. Between 1977 and 2015, the average reservoir elevation range is 25.4 m and the average minimum reservoir elevation is 725.6 m. See Appendix 1 – Hydrology for more information on operations in 2015.

In 2015, Revelstoke reservoir daily average elevations ranged by 0.9 m between 572.0 m and 572.9 m. Full pool is 573 m and the normal operating range is within 1.5 m (to 571.5 m), although the water licence allowable minimum level is much lower.

A strong El Nino year contributed to severe drought conditions in the U.S. and triggered Columbia River Treaty obligations that resulted in sustained high discharge through Revelstoke Reservoir for most of the sampling season (see Appendix 1 Hydrology).

Nitrite and Nitrate* (NO_2+NO_3 *or NN) – Average NN was similar across stations in Kinbasket reservoir (100-104 µg/L), with the greatest seasonal variation at KIN Wood (Table 2, Figures 2 and 6). Average NN was also similar across stations in Revelstoke reservoir (120-123 µg/L), with the greatest seasonal variation at REV Middle station (Table 2, Figures 3 and 6). Overall NN tends to peak in June and decline into the summer and fall, a trend that remains consistent across reservoirs and years (Figures 2 and 3). In most years, NN monthly profiles tend to remain distinct through the water column until about 60 m where values begin to converge; however, in 2015 depth profiles were much more consistent and values close together (Figure 6), likely reflecting the particularly high and consistent flow through the reservoirs. See Appendices 1 and 3 (Hydrology and CTD Profiles for more information).

Phosphorus (TP/TDP/SRP) – Average Total Phosphorus (TP) in Kinbasket ranged from 2.3–2.8 µg/L with the greatest range at KIN Canoe station (Table 2). In Revelstoke reservoir, average TP ranged from 2.3–3.1 µg/L with the highest seasonal average at REV Middle station (Table 2). This high average is a result of two unusually high TP results at 5 m in June and August at REV Middle (10.9 and 15.9 µg/L respectively).

Average Total Dissolved Phosphorus (TDP) in Kinbasket and Revelstoke reservoirs was at or close to the detection limit (2.1–2.3 µg/L and 2.1–2.2 µg/L, respectively) (Table 2) with a maximum of 4.8 µg/L at KIN Canoe in April at 15 m and 5.9 µg/L at REV Middle in April at 75 m (Table 2). High TDP values can be errors as TP from the same samples can be lower, as was the case the REV Middle sample. Occasionally TP values returned are lower than TDP which can happen in systems that have particularly low phosphorus levels or can occur through lab or field contamination. For the purpose of analysis, all values returned at <2.0 µg/L (DL) are transformed to 2.0 µg/L. A substantial portion of samples from both reservoir were below the 2.0 µg/L detection: 86% in Kinbasket reservoir and 78% in Revelstoke reservoir.

Soluble Reactive Phosphorus (SRP) values across Kinbasket and Revelstoke reservoir stations were on average 1.1 to 1.4 µg/L with 73% of values below the detection limit of 1.0 µg/L in Kinbasket and 60% in Revelstoke reservoir. Highest values in Kinbasket occurred in KIN Columbia (5.0 µg/L in August at 2 m) and at REV Middle (4.3 µg/L in July at 15 m) (Table 2). These is little seasonal or depth trend evident in SRP values and the high values are not usually mirrored in the TP or TDP data (Figures 2, 3,and 7).

Alkalinity and Conductivity – Alkalinity was higher in Kinbasket reservoir, average seasonal values ranging from 61 to 75 mg$CaCO_3$/L in Kinbasket and from 54 to 58 mg$CaCO_3$/L in Revelstoke reservoir (Table 2). Average seasonal conductivity is also higher in Kinbasket (147-179 µS/cm) than in Revelstoke (133-141 µS/cm) (Table 2; Figures 4, 5). Unlike most years where conductivity in Revelstoke reservoir reaches a low in July, in 2015, conductivity values increased following June and remained higher than other years (Figure 5a).

pH and Turbidity - pH varies little and is always slightly alkaline. Average turbidity was similar across most stations (0.3 – 1.2 NTUs) (Table 2) although KIN Wood and REV Middle had the highest point sample turbidity levels (10 and 5.9 NTUs, respectively).

Silica (Si) – Silica concentrations were similar across stations in each reservoir with a small decline through the sampling season and tending to begin to increase in the fall (Figure 8). Reservoir silica averages ranged from 2.7 to 3.1 mg/L (Table 2; Figure 8).

Secchi – Secchi depths averaged from 5.2 – 8.3 m across the four Kinbasket reservoir stations in 2013 and from 5.1 – 6.3 m in Revelstoke (Table 2; Figure 9). Secchi values were generally lowest in June at Kinbasket stations with generally increasing depth into the fall. In Revelstoke reservoir, however, Secchi depths tended to decrease through freshet and into the fall possibly reflecting the high discharge conditions in 2015 and a particularly strong rain event on September 20, 2015 (Figure 9).

Table 2**.** Average water chemistry values for all depths combined at Kinbasket (Apr-Oct) and Revelstoke (Apr-Oct) reservoir stations, sampled monthly, 2015. Range of values in parentheses.

Parameter	**Units**	**STATIONS**						
		KIN Forebay	***KIN Canoe***	***KIN Wood***	***KIN Columbia***	***REV Forebay***	***REV Middle***	***REV Upper***
NO_2+NO_3 (NN)	µg/L	102 (68.3-143)	104 (72.5-135)	100 (60.7-168)	100 (58.4-147)	123 (64.3-168)	123 (67.0-209)	120 (97.7-147)
TP*	µg/L	2.3 (2.0-4.7)	2.8 (2.0-13.4)	2.7 (2.0 – 6.7)	2.3 (2.0-5.6)	2.5 (2.0 – 4.4)	3.1 (2.0 – 10.9)	2.3 (2.0 – 4.2)
TDP*	µg/L	2.1 (2.0 – 2.8)	2.2 (2.0 – 4.8)	2.1 (2.0 – 3.0)	2.3 (2.0 –9.7)	2.2 (2.0 – 4.8)	2.1 (2.0 – 5.9)	2.1 (2.0 – 3.1)
SRP*	µg/L	1.2 (1.0 – 2.5)	1.2 (1.0 – 3.7)	1.1 (1.0 – 2.3)	1.4 (1.0 – 5.0)	1.1 (1.0 – 2.6)	1.4 (1.0 – 4.3)	1.3 (1.0 – 2.2)
Alkalinity	mg $CaCO_3$/L	64 (56–80)	61 (37-77)	64 (55-100)	75 (59-92)	55 (37-62)	54 (36–63)	58 (45–66)
pH		7.9 (7.7 – 8.3)	8.0 (7.8 – 9.0)	8.0 (7.8 – 9.4)	8.0 (7.8 – 9.1)	7.9 (7.5 – 8.0)	7.9 (7.7 – 8.0)	7.9 (7.7 – 8.0)
Conductivity	µS/cm	156 (136-192)	147 (103 - 184)	151 (135 - 173)	179 (145 - 220)	133 (93.9 - 162)	130 (90.1 - 15)	141 (115-159)
Turbidity[ǂ]	NTU	0.3 (0.1 – 1.5)	0.4 (0.0 – 2.2)	1.2 (0.2 – 10)	0.7 (0.2 – 3.5)	0.6 (0.1 – 2.4)	1.1 (0.2 – 5.6)	0.6 (0.2 – 1.2)
Silica**	mg/L	3.0 (2.5 – 3.2)	2.9 (2.5 – 3.3)	2.7 (2.4 – 3.1)	2.7 (2.2 – 3.3)	3.1 (2.6 – 3.6)	3.1 (2. – 3.7)	3.2 (2.8 – 3.6)
Secchi	m	8.3 (6.0 - 11)	6.1 (2.5 - 7.5)	5.7 (3.8 - 8.4)	5.2 (4.0 - 8.6)	6.3 (2.0 - 9.5)	5.1 (2.0 - 8.3)	5.2 (2.8 - 12)

*Laboratory detection limit for SRP=1.0 µg/L, for TP/TDP=2.0 µg/L
**Silica values are from a single 0-20 integrated sample per month.

4. Discussion

The 2015 results represent the eighth year of sampling sessions on Kinbasket and Revelstoke reservoirs, adding to the dataset begun in 2008. Results from 2008 are not included in summary charts as the sampling season began in July. With this increasing dataset, seasonal and spatial comparisons and trends are beginning to emerge and will be the subject of analysis in the next synthesis report following the 2015 monitoring year and covering the first eight years of the program (2008-2015).

5. References

APHA. 2012. Standard Methods for the Examination of Water and Wastewater, 22nd Edition. American Public Health Association, American Water Works Association, Water Environment Federation. 1496 pp.

Pieters, R., A. Law, and G. Lawrence. 2016. Tributary Water Quality Kinbasket and Revelstoke Reservoirs, 2013. University of British Columbia. Prepared for BC Hydro. Appendix 2 *In* Bray, K. 2016. Kinbasket and Revelstoke Reservoirs Ecological Productivity Monitoring. Progress Report Year 6 (2013). BC Hydro, Study No. CLBMON-3.

Wetzel, R. 2001. Limnology. Third Edition. Academic Press, San Diego, USA.

Acknowledgements

Much appreciation and thanks are extended to Beth Manson and Pierre Bourget who collected, field processed, and shipped water samples.

Figure 1. Location of sampling stations on Kinbasket and Revelstoke reservoirs, 2015.

Figure 2. Seasonal average NN, TP, TDP, and SRP (µg/L) at Kinbasket Reservoir stations, 2009-2015. Note change in laboratory in 2013.

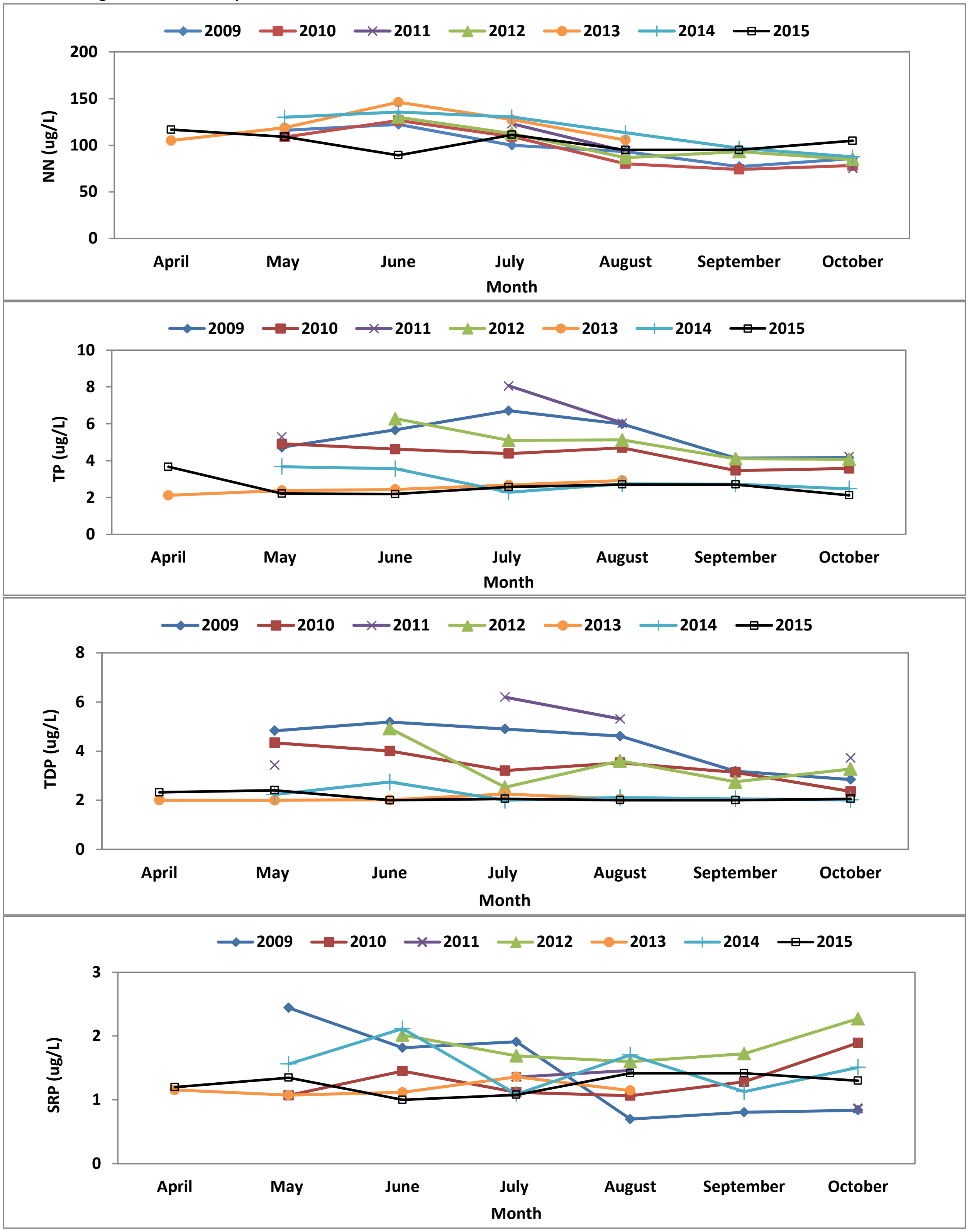


Figure 3. Seasonal average NN, TP, TDP, and SRP (µg/L) at Revelstoke Reservoir stations, 2009-2015. Note change in laboratory in 2013.

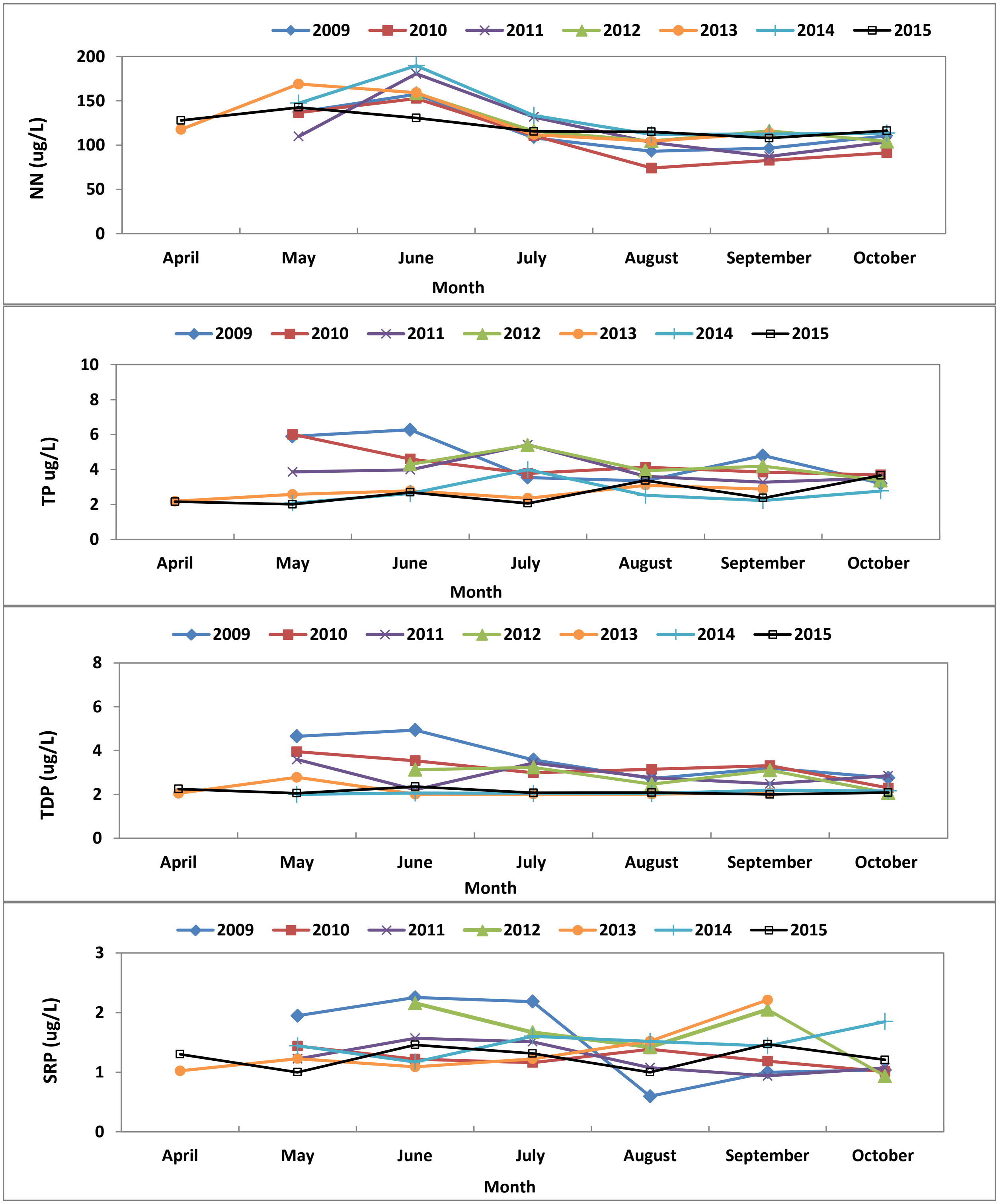
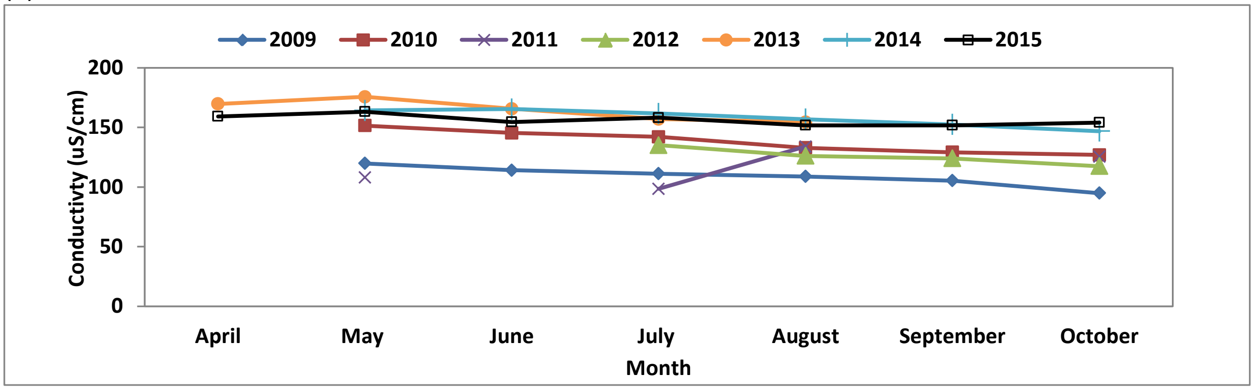


Figure 4. Seasonal average (a) conductivity (µS/cm) and (b) alkalinity ($mgCaCO_3/L$) at Kinbasket Reservoir stations, 2009-2015. Note change in laboratory in 2013.

(a)



(b)

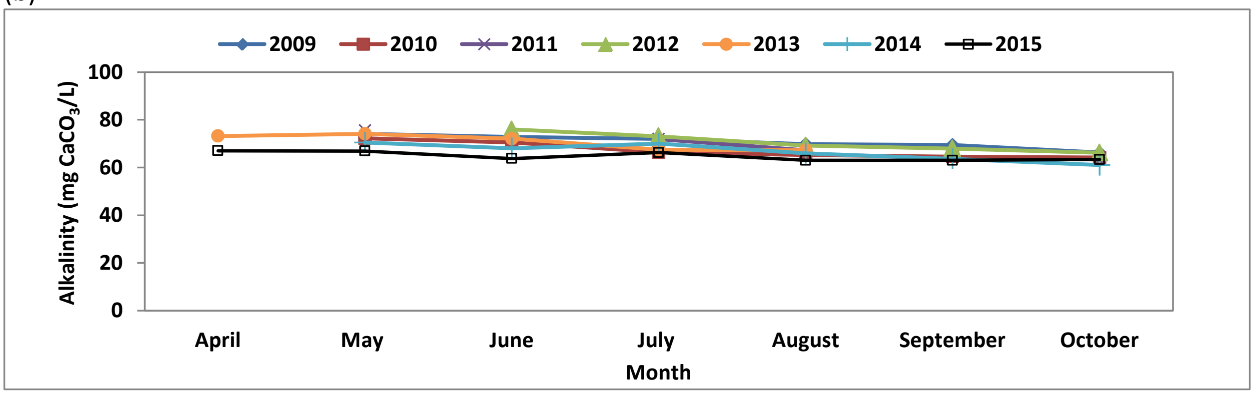
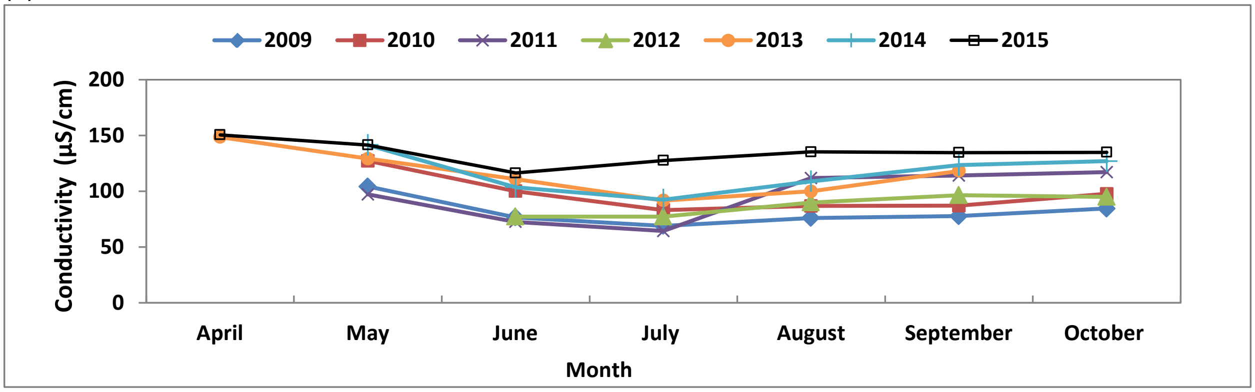


Figure 5. Seasonal average (a) conductivity (µS/cm) and (b) alkalinity (mgCaCO$_3$/L) at Revelstoke Reservoir stations, 2009-2015. Note change in laboratory in 2013.

(a)



(b)

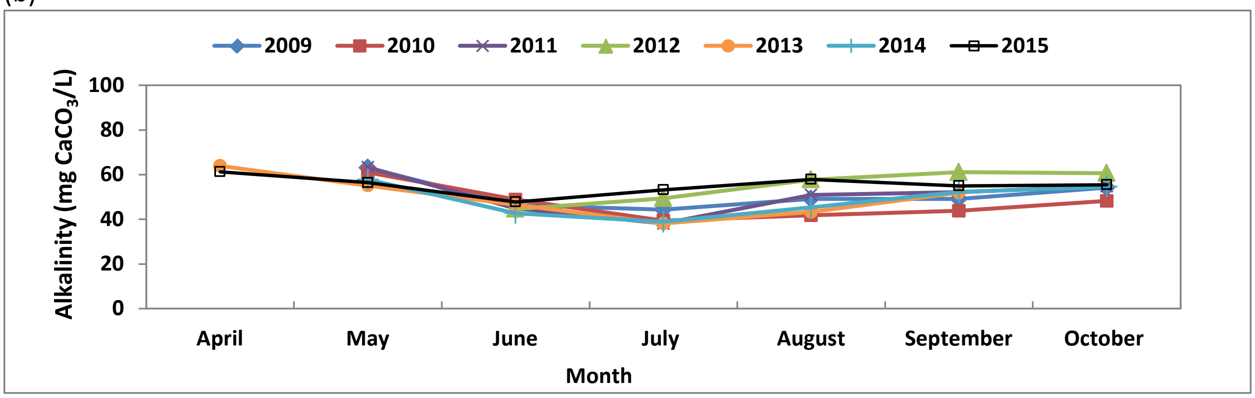
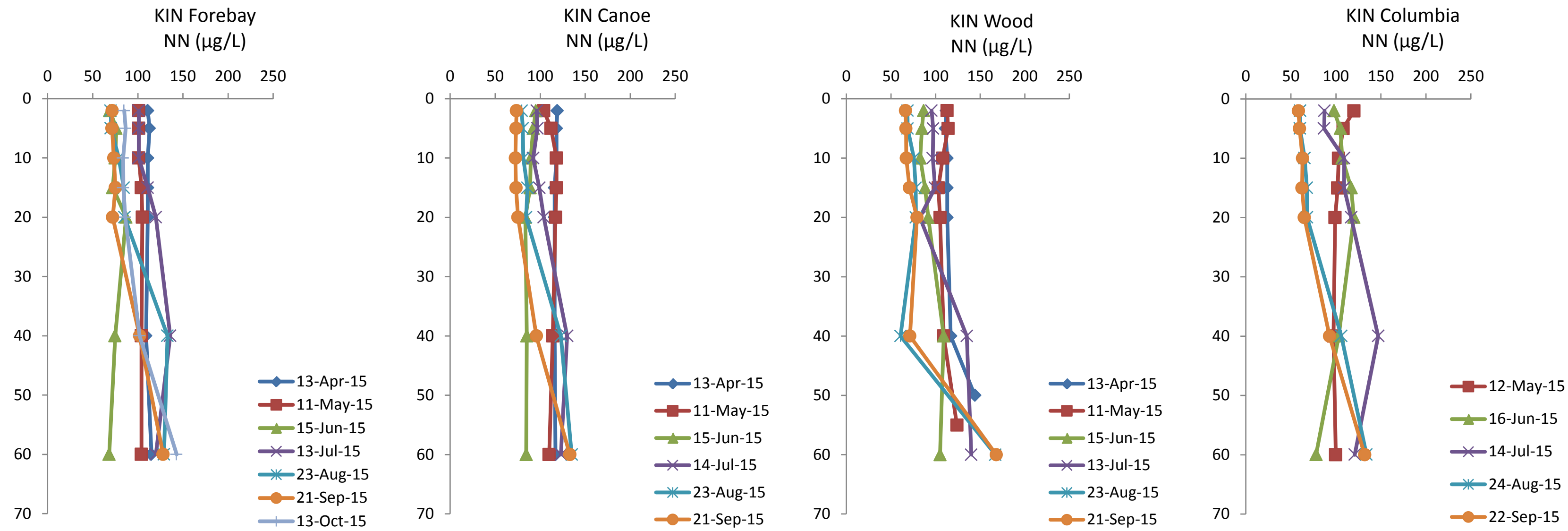
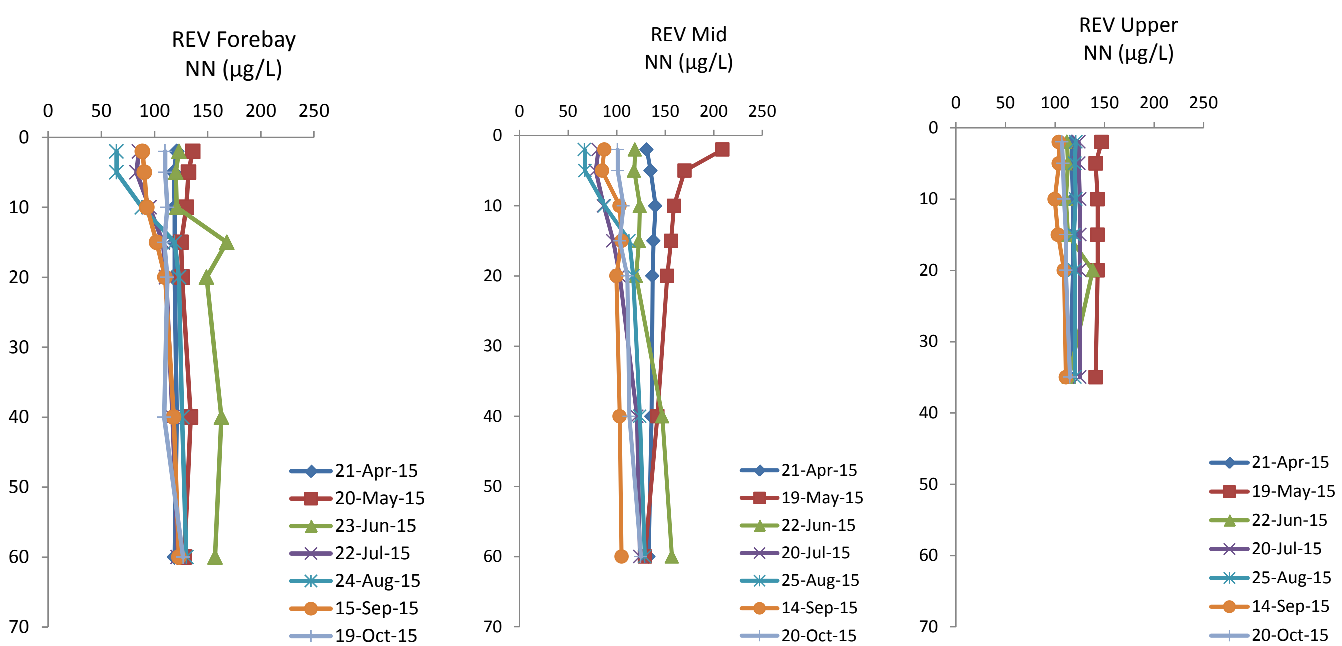


Figure 6. NN (µg/L) depth profiles (0-60m) for Kinbasket and Revelstoke Reservoir stations, 2015.





Note: At KIN Wood a 60m sample depends on reservoir elevation. REV Upper is not deep enough for a 60m sample.

Figure 7. SRP (µg/L) depth profiles (0-60m) for Kinbasket and Revelstoke Reservoir stations, 2015.

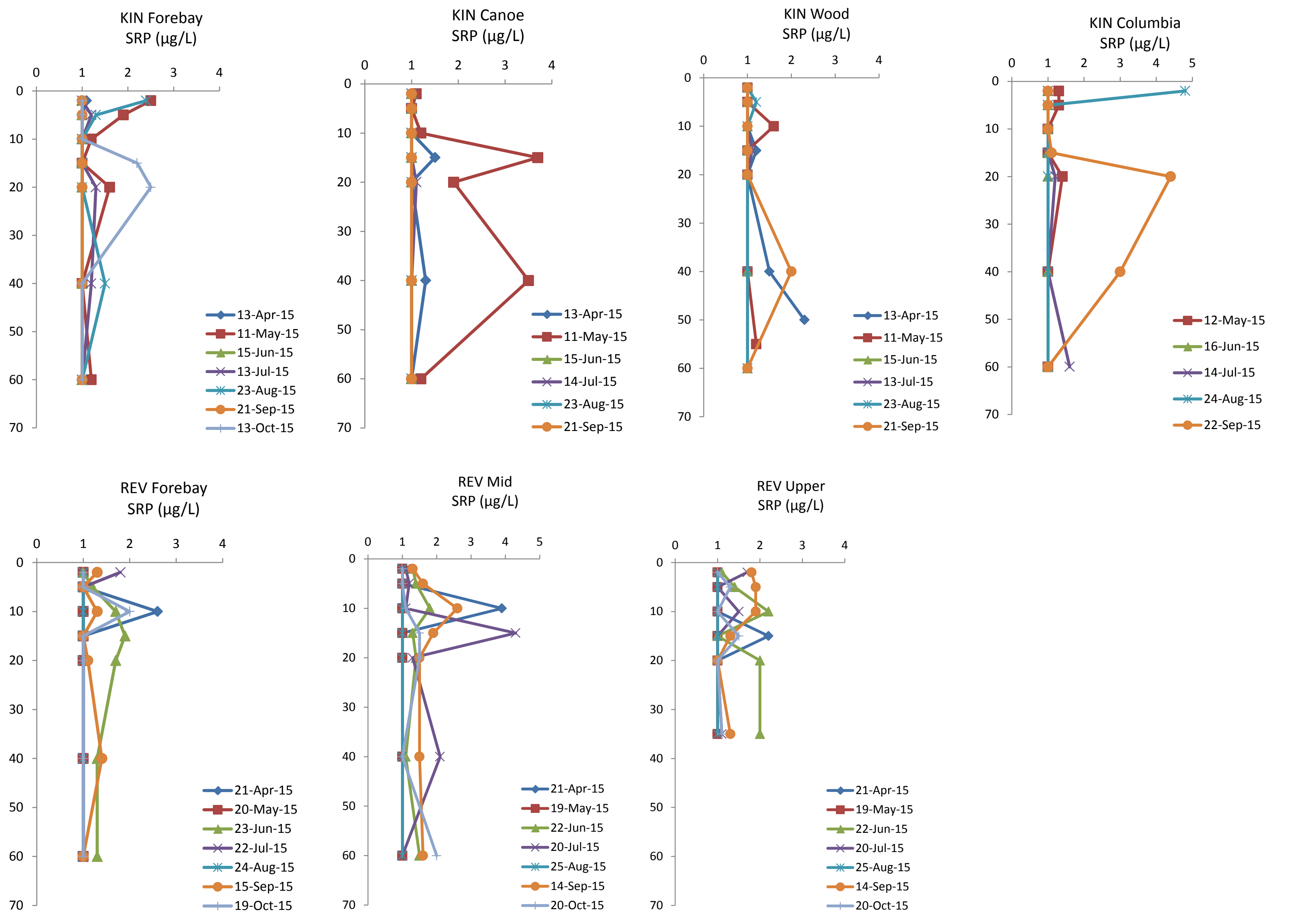
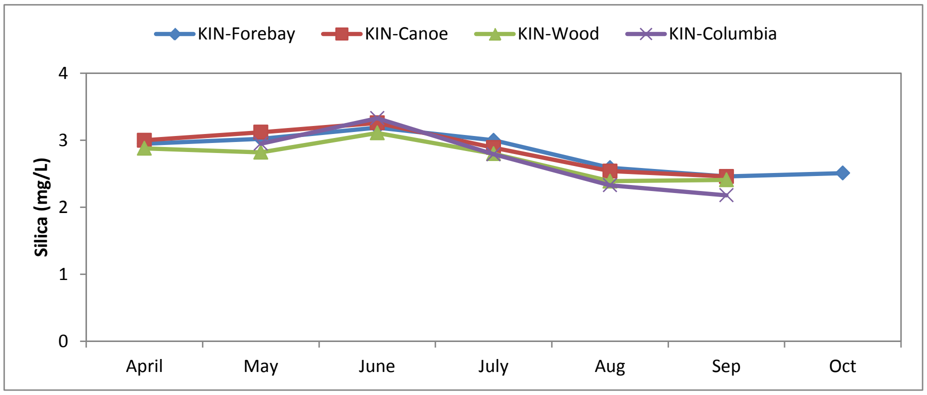
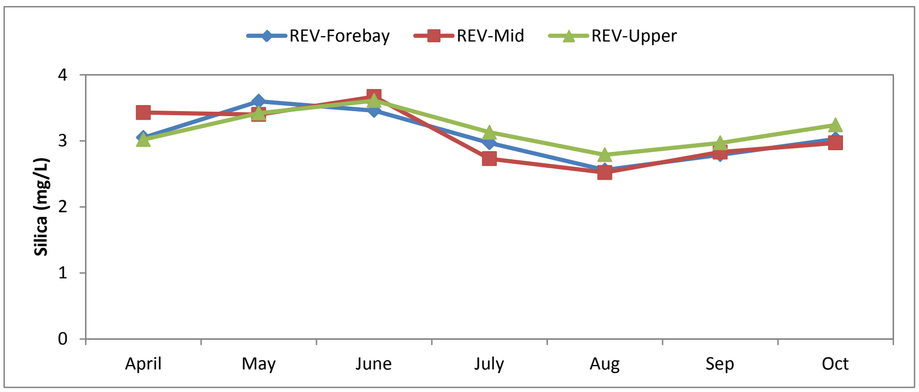


Figure 8. Seasonal silica (mg/L) from a 0-20m integrated tube sample at (a) Kinbasket and (b) Revelstoke stations, 2015.

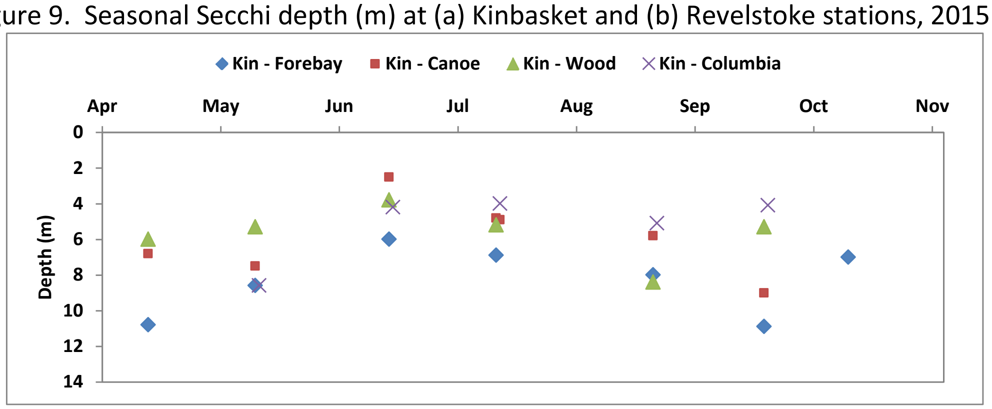


(a)

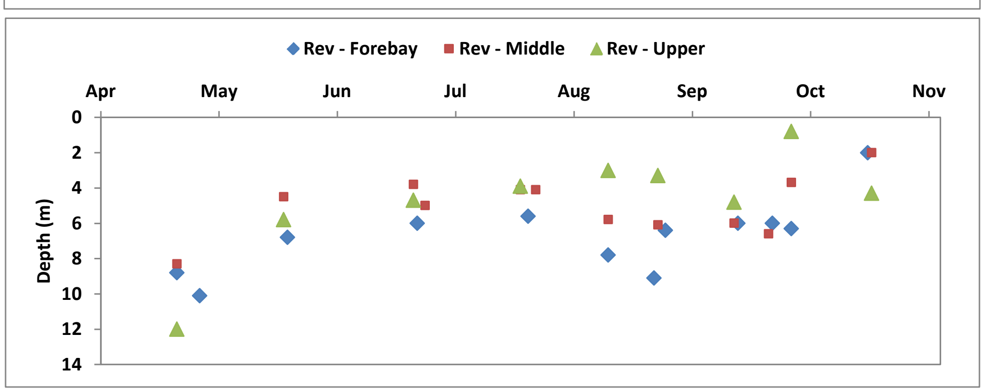


(b)

Figure 9. Seasonal Secchi depth (m) at (a) Kinbasket and (b) Revelstoke stations, 2015.



(a)



(b)

Appendix 1 – Data

Station	Depth	Date	Nitrate/ Nitrite	SRP	TP	TDP	SRS	Alkalinity	pH	Turbidity	Cond.
	m		ug/L	ug/L	ug/L	ug/L	mgSi/L	mgCaCO3/L		(NTU)	uS/cms
KIN FB	2	13-Apr-15	111.0	1.10	2.70	2.40		66.00	7.92	0.16	157.0
	5	13-Apr-15	113.0	1.00	4.20	2.30		65.90	7.87	0.15	158.0
	10	13-Apr-15	111.0	1.00	2.10	2.00		64.90	7.93	0.15	157.0
	15	13-Apr-15	111.0	1.00	4.00	2.50		66.30	7.93	0.15	158.0
	20	13-Apr-15	111.0	1.00	2.00	2.00		67.30	7.93	0.14	159.0
	40	13-Apr-15	109.0	1.00	2.00	2.00		67.80	7.92	0.14	160.0
	60	13-Apr-15	115.0	1.00	2.10	2.00		73.50	7.96	0.12	174.0
	80	13-Apr-15	116.0	1.00	4.70	2.10		74.60	7.97	0.12	176.0
	150	13-Apr-15	135.0	1.00	4.50	2.00		80.10	7.97	0.14	191.0
	2	11-May-15	101.0	2.50	2.20	2.00		60.40	7.93	0.20	149.0
	5	11-May-15	101.0	1.90	2.00	2.00		61.40	7.93	0.17	148.0
	10	11-May-15	101.0	1.20	3.10	2.10		61.50	7.82	0.19	147.0
	15	11-May-15	104.0	1.00	2.00	2.00		60.10	7.92	0.20	147.0
	20	11-May-15	105.0	1.60	2.00	2.00		61.50	7.93	0.21	149.0
	40	11-May-15	104.0	1.00	2.00	2.80		61.70	7.86	0.13	152.0
	60	11-May-15	104.0	1.20	2.00	2.00		68.70	7.89	0.17	163.0
	80	11-May-15	110.0	1.00	2.00	2.00		72.70	7.90	0.15	174.0
	160	11-May-15	128.0	1.20	2.00	2.00		77.60	7.99	0.17	186.0
	2	15-Jun-15	69.0	1.00	2.00	2.00		62.40	7.98	0.49	152.0
	5	15-Jun-15	76.0	1.00	2.00	2.00		60.50	7.97	0.42	147.0
	10	15-Jun-15	75.0	1.00	2.00	2.00		56.30	7.73	0.42	146.0
	15	15-Jun-15	72.2	1.00	2.00	2.00		61.80	7.93	0.42	149.0
	20	15-Jun-15	87.0	1.00	2.00	2.00		59.80	7.98	0.29	149.0
	40	15-Jun-15	74.9	1.00	2.00	2.00		58.20	7.94	1.26	140.0
	60	15-Jun-15	68.3	1.00	2.00	2.00		61.20	7.97	0.39	148.0
	80	15-Jun-15	70.8	1.00	2.00	2.00		66.10	8.01	0.17	162.0
	170	15-Jun-15	81.1	1.00	2.00	2.00		76.80	8.04	0.37	184.0
	2	13-Jul-15	101.0	1.00	2.10	2.00		59.30	7.94	0.42	146.0
	5	13-Jul-15	101.0	1.20	2.50	2.10		60.70	7.87	0.47	146.0
	10	13-Jul-15	101.0	1.00	2.70	2.00		58.20	7.96	0.42	145.0
	15	13-Jul-15	111.0	1.00	2.50	2.00		61.30	7.95	0.33	150.0
	20	13-Jul-15	120.0	1.30	2.50	2.00		63.30	7.95	0.60	154.0
	40	13-Jul-15	136.0	1.20	2.00	2.00		66.30	7.96	0.38	161.0
	60	13-Jul-15	120.0	1.00	2.00	2.00		63.10	7.90	0.40	155.0
	80	13-Jul-15	115.0	1.00	2.00	2.00		70.90	7.95	0.12	168.0
	175	13-Jul-15	130.0	1.40	2.00	2.40		78.90	7.98	0.22	187.0
	2	23-Aug-15	70.0	2.40	2.10	2.00		57.70	7.85	0.33	141.0
	5	23-Aug-15	70.3	1.30	2.00	2.00		57.50	7.76	0.36	142.0
	10	23-Aug-15	78.8	1.00	3.40	2.00		56.50	7.73	0.35	136.0
	15	23-Aug-15	84.5	1.00	2.70	2.00		57.30	7.87	0.38	140.0
	20	23-Aug-15	85.4	1.00	2.30	2.00		56.70	7.88	0.47	140.0
	40	23-Aug-15	133.0	1.50	2.00	2.00		69.60	7.93	0.49	160.0
	60	23-Aug-15	129.0	1.00	2.00	2.00		62.40	7.86	0.51	151.0
	80	23-Aug-15	121.0	1.00	2.00	2.00		71.20	7.86	0.18	166.0
	170	23-Aug-15	133.0	1.10	2.00	2.20		78.30	7.90	0.20	185.0
	2	21-Sep-15	71.7	1.00	2.00	2.00		57.00	7.95	0.28	136.0
	5	21-Sep-15	71.4	1.00	2.00	2.00		57.80	7.98	0.33	138.0
	10	21-Sep-15	73.4	1.00	2.50	2.00		56.60	7.97	0.28	138.0
	15	21-Sep-15	75.1	1.00	2.00	2.00		57.80	7.95	0.28	138.0
	20	21-Sep-15	72.1	1.00	2.00	2.00		58.30	8.04	0.26	141.0
	40	21-Sep-15	102.0	1.00	2.00	2.00		61.40	7.99	1.47	152.0
	60	21-Sep-15	128.0	1.00	2.00	2.00		67.70	8.26	0.27	170.0
	80	21-Sep-15	118.0	1.00	2.00	2.00		66.50	7.71	0.18	173.0
	170	21-Sep-15	133.0	1.00	2.00	2.00		79.50	8.19	0.13	192.0
	2	13-Oct-15	84.8	1.00	2.30	2.10		58.90	7.96	0.41	144.0
	5	13-Oct-15	86.4	1.00	2.00	2.40		58.20	7.85	0.33	142.0
	10	13-Oct-15	83.7	1.00	2.00	2.00		58.20	7.86	0.36	143.0
	15	13-Oct-15	83.9	2.20	2.00	2.00		58.30	7.85	0.38	143.0
	20	13-Oct-15	86.0	2.50	2.10	2.00		58.80	7.86	0.37	143.0
	40	13-Oct-15	102.0	1.00	2.70	2.00		63.30	7.89	0.88	151.0
	60	13-Oct-15	143.0	1.00	2.00	2.00		63.60	7.88	0.25	157.0
	80	13-Oct-15	131.0	1.00	2.00	2.00		71.10	7.94	0.18	173.0

	170	13-Oct-15	143.0	1.00	2.00	2.00		79.60	7.99	0.17	191.0
	0 - 20	11-May-15					3.02				
	0 - 20	15-Jun-15					3.19				
	0 - 20	13-Jul-15					3				
	0 - 20	23-Aug-15					2.59				
	0 - 20	21-Sep-15					2.46				
	0 - 20	13-Oct-15					2.51				
KIN Canoe	2	13-Apr-15	119.0	1.00	2.00	2.00		61.50	7.80	0.24	149.0
	5	13-Apr-15	118.0	1.00	2.20	2.00		63.00	7.84	0.24	147.0
	10	13-Apr-15	118.0	1.00	9.50	3.70		61.90	7.86	0.25	148.0
	15	13-Apr-15	116.0	1.50	7.70	4.80		60.70	7.80	0.25	145.0
	20	13-Apr-15	116.0	1.00	7.60	2.00		61.10	7.89	0.25	148.0
	40	13-Apr-15	116.0	1.30	2.70	2.00		62.10	7.86	0.24	149.0
	60	13-Apr-15	117.0	1.00	2.10	2.00		66.70	7.88	0.18	158.0
	80	13-Apr-15	114.0	2.30	4.40	3.10		74.20	7.94	0.11	172.0
	110	13-Apr-15	127.0	1.60	4.50	2.00		76.70	7.95	0.01	180.0
	2	11-May-15	104.0	1.10	2.00	2.00		62.60	7.97	0.37	153.0
	5	11-May-15	112.0	1.00	2.00	2.00		59.50	7.93	0.30	146.0
	10	11-May-15	118.0	1.20	2.00	2.00		53.40	7.86	0.37	133.0
	15	11-May-15	118.0	3.70	2.00	4.30		51.30	7.84	0.37	129.0
	20	11-May-15	117.0	1.90	2.00	2.00		53.70	7.88	0.51	137.0
	40	11-May-15	114.0	3.50	2.00	2.00		60.10	7.95	0.21	150.0
	60	11-May-15	110.0	1.20	2.10	2.00		67.60	7.97	0.13	164.0
	80	11-May-15	105.0	1.30	2.00	2.00		69.90	7.95	0.12	173.0
	105	11-May-15	117.0	1.00	2.00	2.00		73.70	7.94	0.13	179.0
	2	15-Jun-15	95.2	1.00	2.80	2.00		36.80	7.78	1.00	103.0
	5	15-Jun-15	92.3	1.00	2.80	2.00		38.40	7.78	1.33	104.0
	10	15-Jun-15	89.5	1.00	2.40	2.00		42.20	7.79	1.11	109.0
	15	15-Jun-15	88.8	1.00	2.80	2.00		47.80	7.82	0.86	119.0
	20	15-Jun-15	83.5	1.00	2.00	2.00		58.00	7.92	0.62	143.0
	40	15-Jun-15	85.2	1.00	2.00	2.00		57.60	7.93	0.19	138.0
	60	15-Jun-15	84.5	1.00	2.00	2.00		63.60	7.97	0.17	153.0
	80	15-Jun-15	82.7	1.00	2.00	2.00		67.60	7.99	0.13	163.0
	130	15-Jun-15	108.0	1.00	2.00	2.00		74.40	8.02	0.15	178.0
	2	14-Jul-15	96.2	1.00	2.40	2.00		65.90	7.98	0.62	157.0
	5	14-Jul-15	96.9	1.00	2.10	2.00		64.20	7.97	0.66	152.0
	10	14-Jul-15	92.2	1.00	2.20	2.00		51.60	7.89	0.70	126.0
	15	14-Jul-15	99.0	1.00	2.90	2.30		48.70	7.85	1.20	120.0
	20	14-Jul-15	104.0	1.10	3.40	2.00		48.20	7.86	2.21	122.0
	40	14-Jul-15	130.0	1.00	2.40	2.00		62.00	7.94	0.87	148.0
	60	14-Jul-15	123.0	1.00	2.00	2.00		62.20	7.94	0.23	149.0
	80	14-Jul-15	120.0	1.00	2.00	2.40		71.00	7.95	0.14	167.0
	115	14-Jul-15	124.0	1.00	2.00	2.20		77.10	7.95	0.27	182.0
	2	23-Aug-15	79.4	1.00	2.30	2.00		55.10	7.88	0.44	134.0
	5	23-Aug-15	80.7	1.00	2.20	2.00		53.90	7.85	0.47	134.0
	10	23-Aug-15	81.2	1.00	2.70	2.00		49.50	7.75	0.48	132.0
	15	23-Aug-15	85.8	1.00	13.40	2.00		50.60	7.85	0.52	129.0
	20	23-Aug-15	84.3	1.00	2.20	2.00		56.30	7.87	0.49	136.0
	40	23-Aug-15	123.0	1.00	2.50	2.00		64.10	7.90	0.65	149.0
	60	23-Aug-15	135.0	1.00	2.00	2.00		56.10	7.85	0.37	139.0
	80	23-Aug-15	126.0	2.40	2.00	2.00		67.40	7.86	0.30	159.0
	115	23-Aug-15	128.0	1.00	2.00	2.00		76.10	7.94	0.14	180.0
	2	21-Sep-15	73.7	1.00	2.00	2.00		58.00	8.01	0.36	136.0
	5	21-Sep-15	73.1	1.00	2.00	2.00		55.30	8.11	0.34	137.0
	10	21-Sep-15	72.5	1.00	2.00	2.00		56.20	7.98	0.32	137.0
	15	21-Sep-15	73.1	1.00	2.00	2.00		72.50	8.91	0.30	153.0
	20	21-Sep-15	75.3	1.00	2.00	2.00		65.80	9.01	0.33	153.0
	40	21-Sep-15	95.8	1.00	2.00	2.00		54.70	8.35	0.53	137.0
	60	21-Sep-15	133.0	1.00	2.00	2.00		60.00	8.02	0.15	145.0
	80	21-Sep-15	126.0	1.00	2.00	2.00		70.10	8.01	0.19	166.0
	115	21-Sep-15	122.0	1.00	2.00	2.00		76.50	8.09	0.26	184.0
	0 - 20	13-Apr-15					3.00				
	0 - 20	11-May-15					3.12				
	0 - 20	15-Jun-15					3.26				

	0 - 20	14-Jul-15					2.89				
	0 - 20	23-Aug-15					2.54				
	0 - 20	21-Sep-15					2.46				
KIN Wood	2	13-Apr-15	112.0	1.00	4.30	3.00		64.80	7.91	0.23	154.0
	5	13-Apr-15	111.0	1.00	2.00	2.00		66.40	7.91	0.24	156.0
	10	13-Apr-15	113.0	1.00	3.40	2.00		66.50	7.93	0.24	154.0
	15	13-Apr-15	113.0	1.20	2.00	2.00		64.40	7.92	0.26	156.0
	20	13-Apr-15	113.0	1.00	2.90	2.00		66.20	7.94	0.27	157.0
	40	13-Apr-15	117.0	1.50	2.40	2.00		65.90	7.83	0.34	157.0
	50	13-Apr-15	144.0	2.30	4.70	2.40		68.40	7.95	0.73	165.0
	2	11-May-15	113.0	1.00	2.00	2.00		62.10	7.99	0.34	155.0
	5	11-May-15	114.0	1.00	2.00	2.00		62.70	7.97	0.62	155.0
	10	11-May-15	108.0	1.60	2.00	2.00		63.80	7.99	0.32	154.0
	15	11-May-15	103.0	1.00	6.70	2.00		63.50	7.96	0.24	153.0
	20	11-May-15	105.0	1.00	2.00	2.00		62.50	7.94	0.20	152.0
	40	11-May-15	109.0	1.00	2.00	2.00		64.10	7.85	0.24	154.0
	55	11-May-15	124.0	1.20	2.00	2.00		65.10	7.93	0.45	160.0
	2	15-Jun-15	86.5	1.00	2.00	2.00		59.60	7.97	1.33	144.0
	5	15-Jun-15	84.7	1.00	2.00	2.00		60.60	7.98	0.90	144.0
	10	15-Jun-15	82.7	1.00	2.00	2.00		55.10	7.93	0.58	136.0
	15	15-Jun-15	88.1	1.00	2.30	2.00		58.40	7.95	0.48	145.0
	20	15-Jun-15	91.7	1.00	2.50	2.00		63.60	7.98	1.06	151.0
	40	15-Jun-15	109.0	1.00	3.50	2.00		61.80	7.98	4.69	146.0
	60	15-Jun-15	105.0	1.00	2.00	2.00		65.30	8.00	0.76	157.0
	2	13-Jul-15	95.4	1.00	2.30	2.00		63.40	7.78	0.76	154.0
	5	13-Jul-15	97.3	1.00	3.40	2.00		63.70	7.97	0.62	153.0
	10	13-Jul-15	96.8	1.00	4.00	2.00		62.70	7.97	0.50	149.0
	15	13-Jul-15	99.3	1.10	2.40	2.50		61.50	7.93	0.71	147.0
	20	13-Jul-15	82.3	1.00	3.20	2.00		56.60	7.95	4.16	135.0
	40	13-Jul-15	135.0	1.00	5.20	2.00		64.50	7.96	7.09	144.0
	60	13-Jul-15	140.0	1.00	2.00	2.00		69.40	7.98	0.76	164.0
	2	23-Aug-15	68.5	1.00	2.20	2.00		58.50	7.88	0.29	142.0
	5	23-Aug-15	68.6	1.20	3.00	2.00		59.70	7.90	0.34	144.0
	10	23-Aug-15	75.7	1.00	2.30	2.00		55.40	7.89	0.46	141.0
	15	23-Aug-15	77.6	1.00	2.30	2.00		57.10	7.87	0.57	141.0
	20	23-Aug-15	77.9	1.00	2.40	2.00		59.60	7.88	0.65	141.0
	40	23-Aug-15	60.7	1.00	3.40	2.00		58.80	7.87	3.28	136.0
	60	23-Aug-15	167.0	1.00	2.60	2.00		69.80	7.95	1.22	165.0
	2	21-Sep-15	66.2	1.00	2.00	2.00		99.70	9.39	0.44	173.0
	5	21-Sep-15	66.8	1.00	2.00	2.00		60.20	8.26	0.52	141.0
	10	21-Sep-15	67.1	1.00	2.00	2.00		83.90	9.24	0.53	166.0
	15	21-Sep-15	70.7	1.00	2.00	2.00		58.80	8.15	0.57	141.0
	20	21-Sep-15	79.1	1.00	2.00	2.00		57.30	7.98	0.51	138.0
	40	21-Sep-15	71.2	2.00	2.50	2.00		63.20	8.18	10.10	147.0
	60	21-Sep-15	168.0	1.00	2.00	2.00		73.10	8.12	2.91	171.0
	0 - 20	13-Apr-15					2.88				
	0 - 20	11-May-15					2.82				
	0 - 20	15-Jun-15					3.11				
	0 - 20	13-Jul-15					2.80				
	0 - 20	23-Aug-15					2.39				
	0 - 20	21-Sep-15					2.41				
KIN Col	2	12-May-15	120.0	1.30	2.00	3.80		67.50	8.05	0.42	168.0
	5	12-May-15	108.0	1.30	2.00	2.00		71.80	8.06	0.22	172.0
	10	12-May-15	103.0	1.00	2.00	2.00		74.80	8.07	0.21	180.0
	15	12-May-15	102.0	1.00	2.00	3.90		75.50	8.05	0.18	182.0
	20	12-May-15	99.1	1.40	2.00	2.00		75.90	8.07	0.35	185.0
	40	12-May-15	97.4	1.00	2.00	9.70		77.90	8.03	0.19	190.0
	60	12-May-15	99.8	1.00	2.00	2.00		82.90	8.05	0.21	202.0
	80	12-May-15	104.0	1.00	2.00	2.00		85.30	8.06	0.20	207.0
	160	12-May-15	127.0	1.00	2.00	2.00		89.00	7.95	0.26	216.0
	2	16-Jun-15	97.8	1.00	2.20	2.00		72.40	8.06	0.71	174.0
	5	16-Jun-15	105.0	1.00	2.10	2.00		74.60	8.07	0.82	175.0
	10	16-Jun-15	107.0	1.00	2.20	2.00		73.20	8.05	0.83	173.0
	15	16-Jun-15	117.0	1.00	2.00	2.00		76.50	8.08	0.97	180.0
	20	16-Jun-15	120.0	1.00	2.00	2.00		76.70	8.07	1.04	181.0

	40	16-Jun-15	103.0	1.00	2.50	2.00		78.00	8.08	2.07	184.0
	60	16-Jun-15	78.0	1.00	2.00	2.00		77.30	8.08	0.23	187.0
	80	16-Jun-15	82.0	1.00	2.00	2.00		83.40	8.10	0.15	197.0
	165	16-Jun-15	88.7	1.00	2.00	2.00		87.30	8.12	0.17	209.0
	2	14-Jul-15	87.3	1.00	2.50	2.10		73.40	8.03	0.78	173.0
	5	14-Jul-15	86.9	1.00	2.30	2.00		73.50	8.04	0.67	174.0
	10	14-Jul-15	109.0	1.00	2.90	2.00		69.30	8.00	1.15	162.0
	15	14-Jul-15	109.0	1.00	2.80	2.00		67.60	7.98	2.19	160.0
	20	14-Jul-15	117.0	1.20	2.40	2.00		71.10	8.00	1.58	164.0
	40	14-Jul-15	147.0	1.00	2.80	2.00		75.60	7.83	1.17	177.0
	60	14-Jul-15	121.0	1.60	2.00	2.00		80.30	8.01	0.26	190.0
	80	14-Jul-15	117.0	1.30	2.20	2.00		84.60	8.03	0.20	200.0
	170	14-Jul-15	129.0	1.40	2.00	2.00		90.00	8.04	0.28	215.0
	2	24-Aug-15	60.3	4.80	3.10	2.00		63.50	7.90	0.61	150.0
	5	24-Aug-15	60.1	1.00	2.60	2.00		63.30	7.91	0.75	150.0
	10	24-Aug-15	65.2	1.00	2.70	2.00		60.50	7.89	0.60	147.0
	15	24-Aug-15	67.7	1.00	2.70	2.00		59.20	7.88	0.67	145.0
	20	24-Aug-15	67.9	1.00	2.70	2.00		61.10	7.89	1.15	148.0
	40	24-Aug-15	106.0	1.00	2.10	2.00		68.50	7.92	1.05	159.0
	60	24-Aug-15	134.0	1.00	2.10	2.00		80.60	7.96	0.44	193.0
	80	24-Aug-15	123.0	4.30	2.00	2.00		84.80	7.98	0.19	200.0
	170	24-Aug-15	142.0	5.00	2.10	2.00		91.90	7.91	0.33	220.0
	2	22-Sep-15	58.4	1.00	2.00	2.00		61.10	7.93	0.86	151.0
	5	22-Sep-15	59.7	1.00	2.00	2.00		84.00	9.13	0.86	178.0
	10	22-Sep-15	63.0	1.00	2.00	2.00		62.50	8.00	0.97	151.0
	15	22-Sep-15	62.4	1.10	2.00	2.00		61.40	7.99	0.88	152.0
	20	22-Sep-15	64.9	4.40	2.00	2.00		62.40	7.98	1.10	164.0
	40	22-Sep-15	93.0	3.00	5.60	2.00		67.10	8.04	3.45	160.0
	60	22-Sep-15	132.0	1.00	2.00	2.00		79.10	8.08	0.53	192.0
	80	22-Sep-15	121.0	1.00	2.00	2.00		87.90	8.13	0.24	216.0
	170	22-Sep-15	140.0	1.00	2.00	2.00		91.10	8.09	0.47	220.0
	0 - 20	12-May-15					2.95				
	0 - 20	16-Jun-15					3.33				
	0 - 20	14-Jul-15					2.79				
	0 - 20	24-Aug-15					2.33				
	0 - 20	22-Sep-15					2.18				
REV FB	2	21-Apr-15	121.0	1.00	2.00	2.10		60.90	7.86	0.19	147.0
	5	21-Apr-15	118.0	1.00	2.00	2.00		60.60	7.86	0.18	147.0
	10	21-Apr-15	119.0	2.60	2.00	2.30		61.50	7.88	0.19	148.0
	15	21-Apr-15	119.0	1.00	2.00	2.00		58.20	7.87	0.22	148.0
	20	21-Apr-15	119.0	1.00	2.00	2.00		61.80	7.89	0.52	148.0
	40	21-Apr-15	121.0	1.00	2.00	2.00		59.80	7.88	0.19	147.0
	60	21-Apr-15	119.0	1.00	2.00	2.00		60.40	7.89	0.17	148.0
	80	21-Apr-15	118.0	1.00	2.00	2.00		59.40	7.91	0.23	148.0
	110	21-Apr-15	121.0	1.00	3.60	2.00		60.80	7.85	2.39	147.0
	2	20-May-15	136.0	1.00	2.00	2.00		54.90	7.94	0.37	139.0
	5	20-May-15	132.0	1.00	2.00	2.00		54.60	7.91	0.35	139.0
	10	20-May-15	130.0	1.00	2.10	2.00		54.80	7.93	0.32	139.0
	15	20-May-15	125.0	1.00	2.00	2.00		57.30	7.92	0.21	139.0
	20	20-May-15	126.0	1.00	2.00	2.00		58.00	7.93	0.22	140.0
	40	20-May-15	134.0	1.00	2.00	2.00		60.20	7.97	0.13	162.0
	60	20-May-15	128.0	1.00	2.00	2.00		60.20	7.92	0.25	149.0
	80	20-May-15	128.0	1.00	2.00	2.00		58.90	7.91	0.14	150.0
	110	20-May-15	123.0	1.00	2.00	2.00		59.20	7.91	0.20	148.0
	2	23-Jun-15	123.0	1.00	3.30	2.00		45.00	7.80	0.38	109.0
	5	23-Jun-15	120.0	1.20	2.50	3.90		44.50	7.77	0.48	109.0
	10	23-Jun-15	121.0	1.70	2.70	4.00		44.00	7.78	0.46	108.0
	15	23-Jun-15	168.0	1.90	2.80	2.20		44.30	7.74	0.60	107.0
	20	23-Jun-15	149.0	1.70	3.20	4.80		41.30	7.54	0.65	103.0
	40	23-Jun-15	163.0	1.30	2.50	2.40		48.50	7.80	0.39	114.0
	60	23-Jun-15	157.0	1.30	2.20	2.00		61.30	7.86	0.19	144.0
	80	23-Jun-15	146.0	1.10	2.70	2.10		60.60	7.89	0.63	148.0
	115	23-Jun-15	141.0	1.50	2.20	2.20		62.10	7.86	0.26	147.0
	2	22-Jul-15	85.4	1.80	2.50	2.00		37.30	7.78	0.65	94.4
	5	22-Jul-15	83.1	1.00	2.30	2.00		37.30	7.49	0.62	93.9

	10	22-Jul-15	95.3	1.00	2.40	2.00		37.10	7.77	0.63	94.4
	15	22-Jul-15	108.0	1.00	2.40	2.00		45.50	7.80	0.59	112.0
	20	22-Jul-15	111.0	1.00	2.00	2.00		50.20	7.83	0.55	122.0
	40	22-Jul-15	117.0	1.00	2.10	2.00		49.80	7.83	0.50	127.0
	60	22-Jul-15	122.0	1.00	2.00	2.00		50.20	7.79	0.49	124.0
	80	22-Jul-15	157.0	1.00	2.00	3.90		58.70	7.86	0.26	146.0
	110	22-Jul-15	158.0	1.00	2.00	2.00		60.40	7.89	0.31	151.0
	2	24-Aug-15	64.3	1.00	2.20	2.00		41.10	7.86	0.38	99.8
	5	24-Aug-15	64.3	1.00	2.60	2.00		41.00	7.82	0.54	99.1
	10	24-Aug-15	88.2	1.00	4.00	2.00		49.80	7.87	1.06	116.0
	15	24-Aug-15	119.0	1.00	2.90	2.00		59.20	7.91	0.77	138.0
	20	24-Aug-15	123.0	1.00	2.60	2.10		61.10	7.93	0.73	140.0
	40	24-Aug-15	126.0	1.00	4.10	2.00		60.10	7.93	0.59	141.0
	60	24-Aug-15	130.0	1.00	2.90	2.10		57.10	7.88	0.46	136.0
	80	24-Aug-15	159.0	1.00	3.20	2.00		62.30	7.92	0.48	144.0
	115	24-Aug-15	162.0	1.00	2.10	2.00		61.60	7.88	0.49	147.0
	2	15-Sep-15	88.7	1.30	2.80	2.00		51.60	7.96	0.48	125.0
	5	15-Sep-15	90.5	1.00	2.10	2.00		53.30	7.94	0.54	125.0
	10	15-Sep-15	92.9	1.30	2.00	2.00		51.90	7.94	0.53	126.0
	15	15-Sep-15	102.0	1.00	2.60	2.00		53.00	7.90	0.40	128.0
	20	15-Sep-15	110.0	1.10	3.20	2.00		55.20	7.97	0.56	135.0
	40	15-Sep-15	118.0	1.40	3.90	2.00		58.90	7.97	0.57	140.0
	60	15-Sep-15	123.0	1.00	2.00	2.00		55.20	7.96	0.49	141.0
	80	15-Sep-15	152.0	1.30	2.00	2.00		59.70	7.97	0.34	142.0
	110	15-Sep-15	147.0	1.10	2.00	2.00		59.70	7.94	0.34	144.0
	2	19-Oct-15	110.0	1.00	4.40	2.00		54.10	8.00	2.03	133.0
	5	19-Oct-15	110.0	1.00	4.00	2.00		56.10	7.99	2.04	132.0
	10	19-Oct-15	112.0	2.00	3.20	2.00		55.10	8.01	1.91	131.0
	15	19-Oct-15	109.0	1.00	2.80	2.00		54.20	7.98	1.96	132.0
	20	19-Oct-15	112.0	1.00	3.90	2.00		52.80	7.96	1.82	133.0
	40	19-Oct-15	109.0	1.00	2.20	2.00		53.90	8.00	2.29	133.0
	60	19-Oct-15	127.0	1.00	3.00	2.00		57.80	7.88	1.94	138.0
	80	19-Oct-15	155.0	1.00	2.00	2.00		58.20	8.02	<0.10	145.0
	115	19-Oct-15	165.0	1.10	2.00	2.00		58.80	7.99	0.79	145.0
	0 - 20	21-Apr-15					3.05				
	0 - 20	20-May-15					3.60				
	0 - 20	23-Jun-15					3.46				
	0 - 20	22-Jul-15					2.97				
	0 - 20	24-Aug-15					2.56				
	0 - 20	15-Sep-15					2.79				
	0 - 20	19-Oct-15					3.03				
REV Mid	2	21-Apr-15	131.0	1.00	2.00	2.00		58.20	7.86	0.23	145.0
	5	21-Apr-15	135.0	1.00	2.00	2.00		58.30	7.76	0.25	143.0
	10	21-Apr-15	140.0	3.90	2.00	2.30		58.70	7.85	0.26	144.0
	15	21-Apr-15	138.0	1.00	2.00	2.00		57.20	7.84	0.28	145.0
	20	21-Apr-15	137.0	1.00	4.40	2.00		58.60	7.83	0.33	145.0
	40	21-Apr-15	136.0	1.00	2.00	2.00		60.00	7.86	0.24	146.0
	60	21-Apr-15	133.0	1.00	2.00	2.00		59.30	7.86	0.25	149.0
	75	21-Apr-15	144.0	2.30	2.00	5.90		62.50	7.87	0.24	152.0
	2	19-May-15	209.0	1.00	2.00	2.00		58.00	7.94	0.45	142.0
	5	19-May-15	170.0	1.00	2.00	2.60		56.30	7.93	0.37	138.0
	10	19-May-15	159.0	1.00	2.00	2.00		54.00	7.93	0.52	136.0
	15	19-May-15	156.0	1.00	2.00	2.00		55.40	7.94	0.33	140.0
	20	19-May-15	152.0	1.00	2.00	2.00		57.20	7.93	0.32	141.0
	40	19-May-15	142.0	1.00	2.00	2.00		59.10	7.91	0.24	148.0
	60	19-May-15	129.0	1.00	2.00	2.10		61.70	7.83	0.20	151.0
	80	19-May-15	127.0	1.00	2.00	2.00		59.00	7.85	0.26	149.0
	2	22-Jun-15	119.0	1.30	3.30	2.00		37.10	7.70	0.79	92.9
	5	22-Jun-15	118.0	1.40	3.80	2.60		35.70	7.67	0.96	90.1
	10	22-Jun-15	124.0	1.80	2.80	2.00		36.70	7.68	1.08	91.5
	15	22-Jun-15	123.0	1.30	3.00	2.00		37.70	7.68	1.15	91.2
	20	22-Jun-15	120.0	1.40	2.80	2.00		37.00	7.68	1.04	92.9
	40	22-Jun-15	147.0	1.10	3.00	2.10		43.90	7.74	0.64	106.0
	60	22-Jun-15	157.0	1.50	2.50	2.00		61.20	7.88	0.30	144.0
	80	22-Jun-15	146.0	1.00	2.00	2.10		62.50	7.85	0.31	148.0

	2	20-Jul-15	81.2	1.10	2.00	2.00		41.40	7.83	0.65	93.8
	5	20-Jul-15	78.4	1.20	2.00	2.00		41.50	7.85	0.76	94.7
	10	20-Jul-15	86.7	1.10	2.00	2.00		45.80	7.82	1.13	103.0
	15	20-Jul-15	96.3	4.30	2.00	2.00		49.40	7.81	1.10	114.0
	20	20-Jul-15	103.0	1.30	2.00	2.00		51.00	7.81	0.86	122.0
	40	20-Jul-15	121.0	2.10	2.00	2.00		55.40	7.89	1.03	133.0
	60	20-Jul-15	124.0	1.00	2.00	2.00		53.30	7.88	0.49	129.0
	80	20-Jul-15	163.0	1.00	2.00	2.00		61.30	7.95	0.27	145.0
	2	25-Aug-15	67.0	1.00	3.4	2.00		42.90	7.86	0.87	103.0
	5	25-Aug-15	67.4	1.00	2.70	2.10		44.50	7.86	0.85	102.0
	10	25-Aug-15	87.6	1.00	10.90	2.00		48.30	7.90	3.12	115.0
	15	25-Aug-15	113.0	1.00	3.60	2.00		58.90	7.96	1.50	138.0
	20	25-Aug-15	117.0	1.00	3.10	2.00		59.20	7.95	1.30	142.0
	40	25-Aug-15	124.0	1.00	3.60	2.00		61.20	7.95	1.08	140.0
	60	25-Aug-15	129.0	1.00	2.50	2.20		59.40	7.92	0.85	141.0
	75	25-Aug-15	171.0	1.00	3.00	2.00		60.40	7.86	0.56	142.0
	2	14-Sep-15	87.2	1.3	2.00	2.00		52.80	7.93	0.52	126.0
	5	14-Sep-15	84.9	1.60	2.80	2.00		48.20	7.74	0.66	127.0
	10	14-Sep-15	103.0	2.60	3.10	2.00		54.40	7.95	1.37	131.0
	15	14-Sep-15	105.0	1.90	2.50	2.00		55.00	7.80	0.89	134.0
	20	14-Sep-15	99.7	1.50	2.40	2.00		57.10	7.93	0.68	136.0
	40	14-Sep-15	103.0	1.50	2.20	2.00		56.60	7.94	0.77	138.0
	60	14-Sep-15	105.0	1.60	3.10	2.00		55.40	7.88	0.77	138.0
	80	14-Sep-15	150.0	1.70	2.10	2.00		57.40	7.91	0.50	140.0
	2	20-Oct-15	101.0	1.00	5.30	2.00		54.00	7.99	2.71	130.0
	5	20-Oct-15	101.0	1.00	3.40	2.00		53.50	7.98	2.34	131.0
	10	20-Oct-15	107.0	1.10	4.10	2.00		54.70	7.99	3.05	130.0
	15	20-Oct-15	103.0	1.50	7.30	2.00		55.10	7.99	2.76	132.0
	20	20-Oct-15	111.0	1.50	6.10	2.00		53.70	7.99	3.51	133.0
	40	20-Oct-15	113.0	1.00	4.30	2.20		57.10	7.99	2.34	135.0
	60	20-Oct-15	125.0	2.00	5.00	3.00		58.30	8.02	2.85	141.0
	80	20-Oct-15	162.0	1.70	8.90	2.00		59.20	7.97	5.59	140.0
	0 - 20	21-Apr-15					3.43				
	0 - 20	19-May-15					3.4				
	0 - 20	22-Jun-15					3.67				
	0 - 20	20-Jul-15					2.73				
	0 - 20	25-Aug-15					2.52				
	0 - 20	14-Sep-15					2.83				
	0 - 20	20-Oct-15					2.97				
REV Upper	2	21-Apr-15	117.0	1.00	2.00	3.10		63.50	7.88	0.20	159.0
	5	21-Apr-15	117.0	1.00	2.00	2.00		64.30	7.88	0.22	158.0
	10	21-Apr-15	118.0	1.00	2.00	2.00		64.90	7.89	0.19	158.0
	15	21-Apr-15	118.0	2.20	2.00	2.00		65.60	7.88	0.20	159.0
	20	21-Apr-15	118.0	1.00	2.00	2.00		64.80	7.88	0.34	158.0
	35	21-Apr-15	115.0	1.00	2.00	2.00		63.90	7.88	0.20	157.0
	2	19-May-15	147.0	1.00	2.00	2.50		53.90	7.91	0.51	133.0
	5	19-May-15	141.0	1.00	2.00	2.00		54.10	7.92	0.32	137.0
	10	19-May-15	143.0	1.00	2.00	2.00		53.90	7.93	0.49	137.0
	15	19-May-15	143.0	1.00	2.00	2.00		55.40	7.92	0.39	137.0
	20	19-May-15	143.0	1.00	2.00	2.00		53.90	7.91	0.38	137.0
	35	19-May-15	141.0	1.00	2.00	2.00		54.00	7.90	0.43	137.0
	2	22-Jun-15	112.0	1.10	2.60	2.00		44.50	7.74	1.16	115.0
	5	22-Jun-15	113.0	1.40	2.70	2.50		47.70	7.76	0.86	116.0
	10	22-Jun-15	111.0	2.20	2.30	2.00		48.60	7.78	0.67	117.0
	15	22-Jun-15	113.0	1.00	2.20	2.00		49.50	7.77	0.68	120.0
	20	22-Jun-15	138.0	2.00	2.80	2.00		52.70	7.80	0.65	127.0
	35	22-Jun-15	114.0	2.00	2.40	2.20		52.00	7.90	0.59	131.0
	2	20-Jul-15	124.0	1.70	2.00	2.00		62.50	7.94	0.73	147.0
	5	20-Jul-15	124.0	1.00	2.00	2.00		61.80	7.94	0.64	146.0
	10	20-Jul-15	125.0	1.50	2.00	2.00		61.60	7.95	0.61	147.0
	15	20-Jul-15	125.0	1.00	2.00	2.00		63.30	8.03	0.61	149.0
	20	20-Jul-15	125.0	1.00	2.00	2.00		62.10	7.93	0.84	149.0
	35	20-Jul-15	125.0	1.10	2.00	2.00		62.60	7.89	0.63	149.0
	2	25-Aug-15	121.0	1.00	4.20	2.10		64.00	7.88	0.99	150.0

5	25-Aug-15	120.0	1.00	3.40	2.30		64.00	7.97	0.97	150.0
10	25-Aug-15	121.0	1.00	3.00	2.00		64.90	7.98	1.19	150.0
15	25-Aug-15	119.0	1.00	2.70	2.10		64.80	7.96	1.04	150.0
20	25-Aug-15	120.0	1.00	2.10	2.00		64.70	7.96	1.14	150.0
35	25-Aug-15	120.0	1.00	2.90	2.60		64.70	7.89	1.12	145.0
2	14-Sep-15	104.0	1.80	2.10	2.00		54.10	7.94	0.51	137.0
5	14-Sep-15	104.0	1.90	2.00	2.00		56.20	7.94	0.75	137.0
10	14-Sep-15	99.7	1.90	2.00	2.00		55.70	7.91	0.82	136.0
15	14-Sep-15	103.0	1.30	2.30	2.00		53.90	7.94	0.61	136.0
20	14-Sep-15	109.0	1.00	2.00	2.00		55.70	7.91	0.50	135.0
35	14-Sep-15	111.0	1.30	2.00	2.00		54.40	7.96	0.67	137.0
2	20-Oct-15	107.0	1.00	2.50	2.00		54.40	8.00	0.65	134.0
5	20-Oct-15	108.0	1.30	2.70	2.50		55.60	7.99	0.67	135.0
10	20-Oct-15	109.0	1.00	2.80	2.00		54.10	7.99	0.72	136.0
15	20-Oct-15	111.0	1.50	2.00	2.10		55.90	7.99	0.63	136.0
20	20-Oct-15	111.0	1.00	2.30	2.00		56.30	7.99	0.68	136.0
35	20-Oct-15	115.0	1.10	2.00	2.00		54.10	7.97	0.75	134.0
0 - 20	21-Apr-15					3.02				
0 - 20	19-May-15					3.42				
0 - 20	22-Jun-15					3.61				
0 - 20	20-Jul-15					3.13				
0 - 20	25-Aug-15					2.79				
0 - 20	14-Sep-15					2.97				
0 - 20	20-Oct-15					3.24				

Appendix 5

Primary Productivity
Kinbasket and Revelstoke Reservoirs, 2015

Shannon Harris
Ministry of Environment

PRIMARY PRODUCTIVITY IN KINBASKET AND REVELSTOKE RESERVOIRS, 2014 and 2015

Shannon Harris
Ministry of Environment

2017

Acknowledgements

Our thanks are extended to Pierre Bourget of BC Hydro and Beth Manson of Manson Environmental for assistance with the delivery of the field component of this project. Further gratitude is extended to Petra Wypkis (2014) & Morgan Davies (2015) (BCCF) who were the radioactivity technicians and was responsible for sample analysis. Many thanks to Allison Hebert (MOE) for assisting with the processing of the primary productivity and chlorophyll samples. Thanks to Jennifer Sarchuk for the QA/QC of all data and for recalculation of primary productivity rates. Funding was provided by the Columbia River Water Use Plan-Kinbasket Reservoir Fish and Wildlife Information Plan – Monitoring Program – study number: CLBMON-3, Kinbasket and Revelstoke Reservoirs Ecological Productivity Monitoring Program to MOE by a contribution agreement (#0046004).

Introduction

In order to determine trophic status of a lake or reservoir there are a number of criteria that can be used for trophic classification such as chemical characteristics (Total Phosphorus, Total Nitrogen, Total Dissolved Solid, etc) or dominance of particular biological organisms from bacteria to fish. However, it is generally acknowledged that the best methodology for determination of trophic status is using a parameter that can quantitatively determine rate of growth and one that integrates a variety of environmental parameters (Wetzel, 2001). Currently the best existing parameter available is measurement of rates of primary productivity.

In aquatic ecosystems, a vast diversity of phytoplankton species are concurrently observed in a waterbody ranging from small coccoidal cyanobacteria such as *Synechococcus* sp to large chain forming diatoms such as *Tabularia* sp. Aquatic ecosystems dominated by small cells generally support longer food chains compared to the shorter chains supports by larger sized phytoplankton. The relative contribution of each species will directly impact the functioning of the food web and the study of the phytoplankton community provides insight into the ecosystem dynamics of the reservoir.

Our studies examined the size structure of the phytoplankton community in terms of chlorophyll and primary productivity, particularly the relative contribution of three commonly studied fractions-the picoplankton (0.2-2 µm), nanoplankton (2.0-20 µm) and microplankton (>20 µm). This report summarizes the primary productivity studies carried out on Kinbasket and Revelstoke Reservoirs in 2014 and 2015.

Methods

Field & Laboratory

The field sampling strategy and laboratory methodology were consistent with previous study years and can be found in Harris, 2012. Appendix A provides field and incubation information for the study period. It is important to note that the values for primary productivity in this report are different than previously reported values due to calculation error in the alkalinity measurement. For productivity calculations, alkalinity as mg $CaCO_3$/L must be converted to DIC as mg/L and an error was detected in this conversion calculation. Values for primary productivity for all study years have been recalculated and are presented in this report and are a provided in Appendix B.

Results

Photosynthetically active radiation (PAR), defined as the radiation in the 400-700 nm waveband, was generally high in June in both study years averaging ~1200 µmol/m^2/s. PAR was generally low at all stations in July in both study years with the exception of high values measured at Kinbasket in July 2015. PAR was variable in August 2014 and 2015 whereas values were generally low in September at all stations in both study years. With the exception of high light availability in June 2015, PAR was generally extremely low at Revelstoke Forebay measuring < 400 µmol/m^2/s in most months.

In both study years, the mean euphotic zone depth was deepest at Kinbasket Forebay, followed by Revelstoke Forebay and Revelstoke Middle (Appendix A and Figure 1). On average, the euphotic zone depth in Kinbasket Forebay was nearly 2 meters deeper in 2015 at 19.5 m compared to 17.3 m in Kinbasket Forebay in 2014. The euphotic zone depth at Revelstoke Forebay was similar in the two study years averaging 16.5 m and at the Revelstoke Middle station averaging 12.0. (Figure 1).

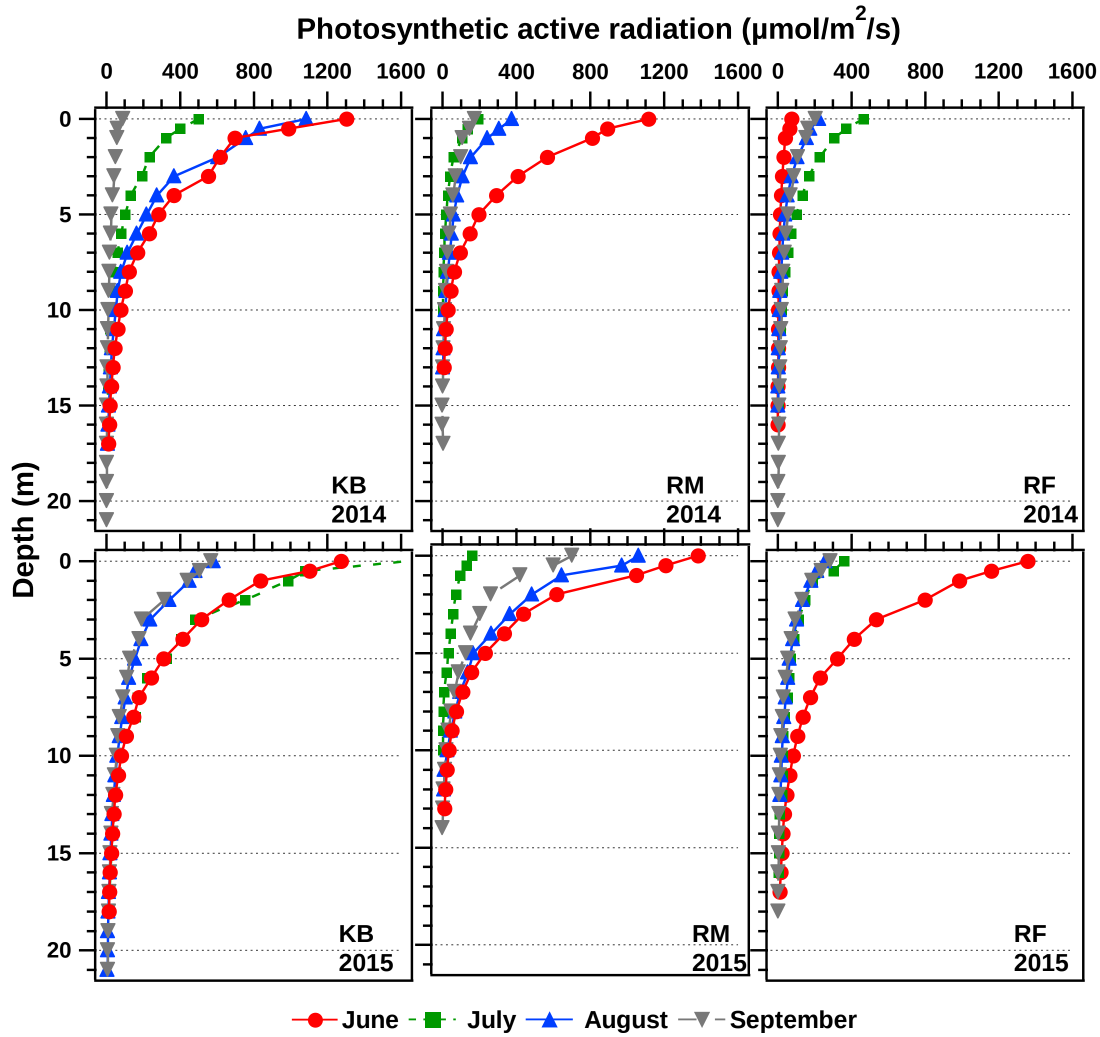


Figure 1 Photosynthetic active radiation (μmol/m^2/s) at Kinbasket Forebay, Revelstoke Middle and Revelstoke Forebay in 2014 and 2015. PAR measurements recorded to the depth of 1% of surface light.

The relative trends between stations in the attenuation coefficient, a measure of the transparency, have been consistent since 2009 (the first year attenuation coefficient was monitored) where the lowest attenuation coefficient was measured at Kinbasket Forebay at 0.27 cm^{-1}, (about 73% transmission m^{-1}) and the highest attenuation coefficient was measured at Revelstoke Middle at 0.37 cm^{-1} (about 63% transmission m^{-1}) (Figure 2). Generally attenuation coefficient for Kinbasket Forebay and Revelstoke Forebay vary within tight bounds, with the lower limit at just under 0.3 cm^{-1} and with an upper limit just over 0.3 cm^{-1} (Figure 2) whereas at Revelstoke Middle, higher and more variable attenuation coefficient values were measured. In 2014, light transmission dropped to 51% transmission m^{-1} (0.49 cm^{-1}) at Revelstoke Middle in July but improved in subsequent months (Figure 2). No large variations in light attenuation were observed in 2015. Generally at all sampling stations, light attenuation was the highest in July and the lowest light attenuation was generally observed in August (Figure 2).

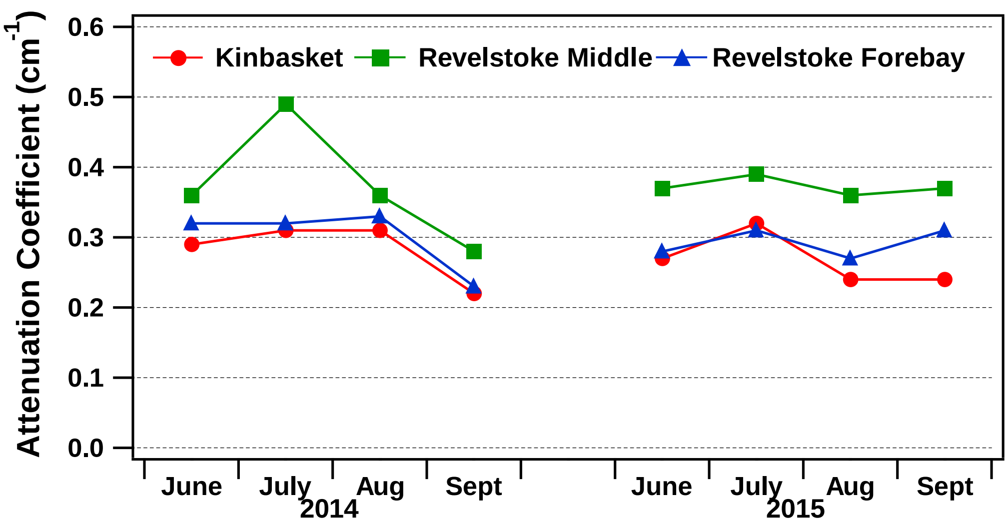


Figure 2 Attenuation coefficients Kinbasket Forebay, Revelstoke Middle and Revelstoke Forebay in 2014 and 2015.

Biomass in Kinbasket and Revelstoke Reservoirs was low ranging from 1-2.5 mg/m^3 (Figure 3), which is indicative of oligotrophic trophic conditions (Wetzel, 2001). In 2014 and 2015, the discrete seasonal averages were 1.79 mg/m^3 in Kinbasket, 0.97 mg/m^3 in Revelstoke Middle, and 1.24 mg/m^3 in Revelstoke Forebay. In most months very little heterogeneity throughout the water column was observed with the exception in June 2014 and 2015 in Revelstoke Middle where a subsurface minimum was observed at ~5-10 m. A subsurface maximum was also observed in June 2015 in Kinbasket Reservoir at 10-15 m which suggests that sampling may have occurred after the spring bloom. As seen in previous study years (Harris, 2012), the depth integrated biomass was higher in Kinbasket Forebay than in Revelstoke Middle or Revelstoke Forebay for all months (Figure 4). Biomass in Kinbasket Forebay generally exceeds 20 mg/m^2 and often exceed 30 mg/m^2 where as at Revelstoke biomass was generally below 20 mg/m^2 and often around 10 mg/m^2 (Figure 4). The seasonal cycles at the three stations differed between study years, specifically in 2014 the seasonal variability in biomass was higher (or less stable) in Kinbasket than in Revelstoke whereas in 2015 seasonal variability was lower or biomass was more stable in Kinbasket Reservoir than in Revelstoke. This suggests different factors are controlling biomass values in the two reservoirs. On average, the average biomass was nearly 2 fold higher in Kinbasket Reservoir at 28.8 mg/m^2 than 15.3 mg/m^2 in Revelstoke Reservoir. The difference between Revelstoke Forebay and Revelstoke Middle is less dramatic at 14.6 for Revelstoke Middle and 15.9 mg/m^2 for Revelstoke Forebay (Table 2) These means are similar to the concentrations measured in 2013, which had means of 26.2, 15.5, and 14.7 mg/m^2 for Kinbasket, Revelstoke Middle and Forebay, respectively (Harris, 2016).

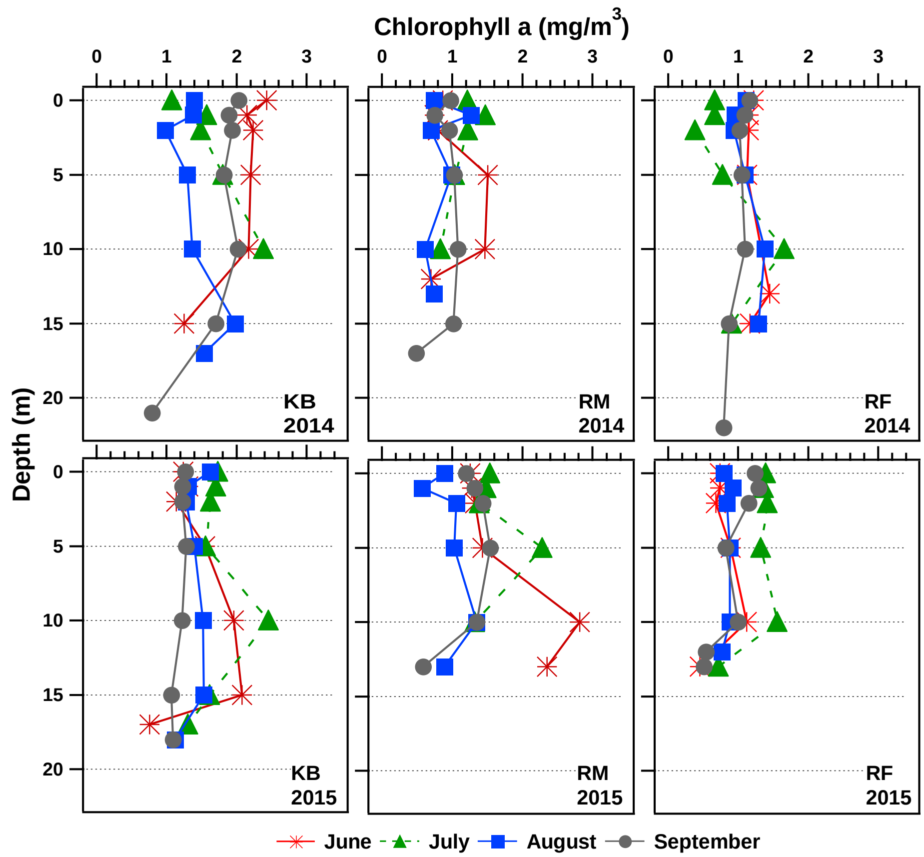


Figure 3 Vertical profiles of chlorophyll *a* (mg/m^3) for Kinbasket Forebay and Revelstoke Middle and Revelstoke Forebay in 2014 & 2015.

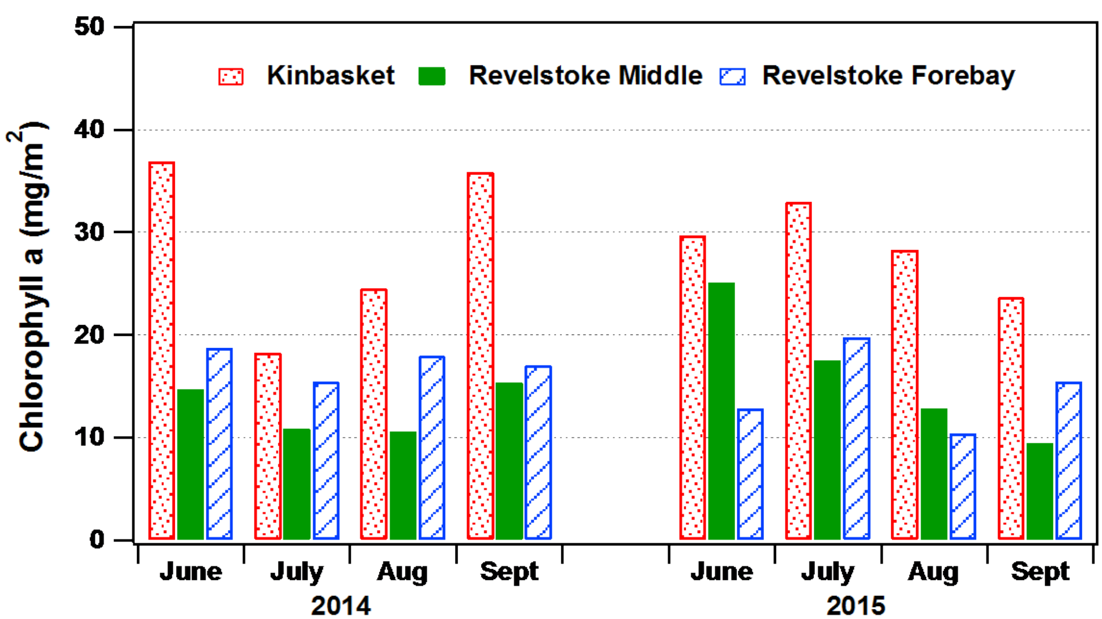


Figure 4 Integrated chlorophyll *a* (mg Chl *a*/m^2) in Kinbasket and Revelstoke in 2014 and 2015.

It is important to examine the size structure of the phytoplankton community as it plays an important role in the structuring of the food web and provides some insight into the community structure and functional relationships in the ecosystem. On average, nanoplankton sized cells (2.0-20 µm) accounted for 46% of the total phytoplankton biomass followed closely by picoplankton sized cells (0.2-2 µm) at 43% whereas the large sized microplankton (>20 µm) accounted for only 11% (Figure 5). Picoplankton and nanoplankton sized cells (cells >20 µm) accounted for 91% and 87% of the biomass in Kinbasket and Revelstoke in 2014 and 2015 respectively; this is similar to the values measured in 2013 where these two size structures accounted for 89% of the biomass (Harris, 2016).

The relative contribution of the three fractions was more variable in 2014 than in 2015 (Figure 5). For instance, at Kinbasket Forebay picoplankton biomass was highest in June and July at nearly 50% of the total biomass while in August and September the relative contribution dropped in half to ~25%. High variability was also measured in the relative contribution of microplankton at Kinbasket Forebay where the microplankton accounted for ~10% in June and July and increased to 30% by September (Figure 5). This seasonal variability in the size composition was generally not measured in 2015 where the contribution of the three size classes was relatively static in Kinbasket and Revelstoke in all study months. On average picoplankton accounted for 44% of the biomass in Kinbasket and Revelstoke followed by nanoplankton accounting for 46% and microplankton accounting for 9%. The relatively high contribution of nanoplankton to the food web should support the growth of large sized zooplankton. The high proportion of picoplankton which, owing to their small size, suggests relative scarcity of available nutrients also suggests the importance of the microbial food web in Kinbasket and Revelstoke (Stockner and Porter, 1988). Microplankton generally accounted for between 10-20% of the community, again suggesting nutrient limitation, specifically limitation of nitrate (Dugdale and Wilkerson, 1998).

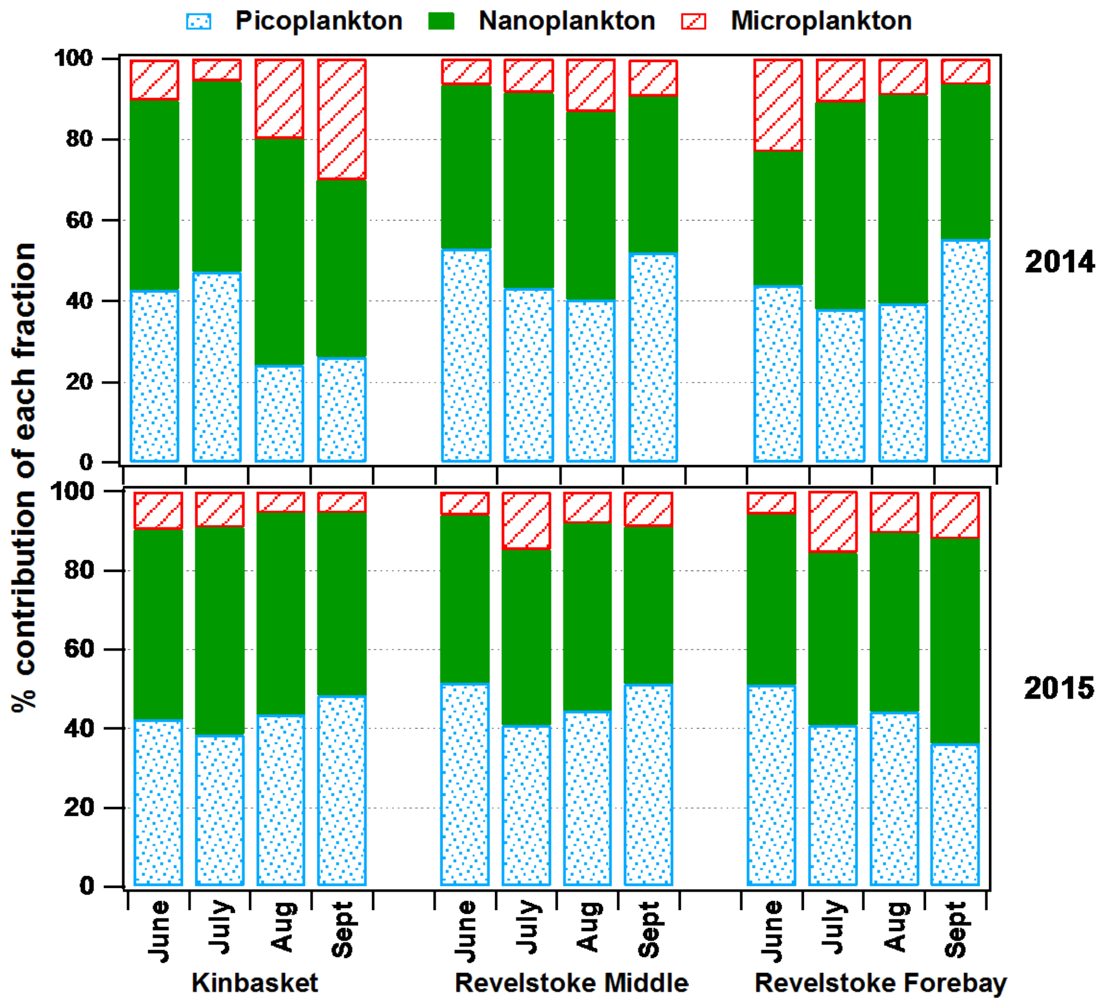


Figure 5 Relative contribution of picoplankton (0.2-2 µm), nanoplankton (2.0-20 µm) and microplankton (>20 µm) to chlorophyll in Kinbasket and Revelstoke in 2014 & 2015.

Primary Productivity

Total primary production of all algal size fractions, measured as the radioactive carbon retained on the 0.2 µm filter, generally did not exceed 200 mg $C/m^2/d$ on Kinbasket Reservoir and 150 mg $C/m^2/d$ on Revelstoke (Figure 6). On average, the seasonal average primary productivity was higher in Kinbasket than in Revelstoke, though on two occasions in July and August 2014, primary productivity was higher at Revelstoke Forebay. On average, primary productivity is 52% higher in Kinbasket than in Revelstoke Middle and 38% higher in Kinbasket Reservoir than in Revelstoke Forebay. Primary productivity varied seasonally in both years and in both reservoirs, as highlighted by the 3 fold increase in Kinbasket in July 2014 to the seasonal peak of 262.1 mg $C/m^2/d$ in September. Similar variability is apparent in the Revelstoke Reservoir in 2014 and 2015 (Figure 6). Although high seasonal variability was observed in both study years, little interannual variability was measured in Kinbasket Reservoir. Primary productivity in Kinbasket Reservoir was 150.9 mg $C/m^2/d$ in 2014 and 152.5 mg $C/m^2/d$ in 2015 which is indicative of oligotrophic state conditions (Wetzel, 2001). While primary productivity in Kinbasket Reservoir was relatively static in 2014 and 2015, primary productivity in Revelstoke Middle dropped in 2015 by 28% from 118 to 81 mg C/m^2/d and by 23% from 125 to 94 mg C/m^2/d in Revelstoke Forebay (Table 2).

This pattern of the highest production at Kinbasket Forebay and the lowest production at Revelstoke Middle was also observed in earlier years (Harris, 2016). Throughout the study period, Kinbasket Forebay has consistently had the highest water transparency as reflected by low attenuation factors whereas Revelstoke had the least transparent water suggesting that physical factors may play an important role in the regulation of primary productivity in Kinbasket and Revelstoke Reservoirs.

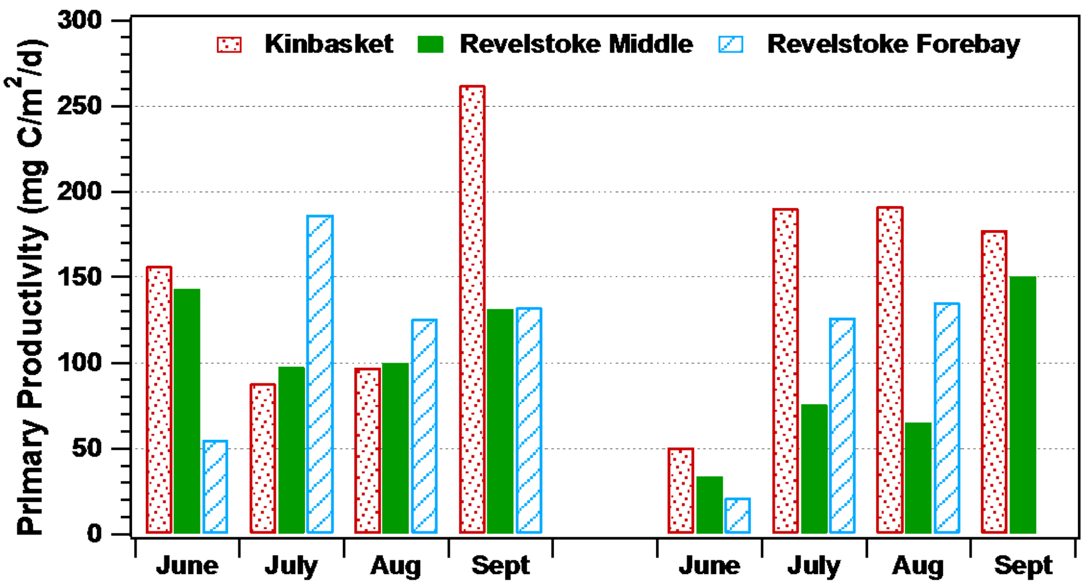


Figure 6 Primary productivity (mg C/m^2/d) in Kinbasket Forebay, Revelstoke Middle and Revelstoke Forebay in 2014 and 2015.

As was observed in early years, production in Kinbasket and Revelstoke in 2014 and 2015 was dominated by phytoplankton less than 20.0 µm in size. Picoplankton and nanoplankton, phytoplankton less than 20.0 µm in size, accounted for 83% of the total production (Figure 7). At Revelstoke Middle and Revelstoke Forebay phytoplankton less than 20.0 µm in size accounted for 85% and 83% of the total production in 2014 and 2015 (Figure 7). Microplankton were the least productive fraction, accounting for on average 17% of total production (Figure 7).

In both study years in Kinbasket Reservoir, the size structure of primary production was similar with nanoplankton as the most productive fraction followed closely by picoplankton and then microplankton (Figure 7). Nanoplankton production accounted for 44% of the total production, followed by picoplankton at 37% and microplankton at 19%. The relative importance of nanoplankton production varied seasonally from a low of 35% in September 2014 to a high of

54% in July 2014 and Aug 2015. Microplankton production was also dynamic in Kinbasket Reservoir in both study years accounting for 7% to 32% of total production. The seasonal trend in the two study years showed differing microplankton production patterns. In 2014, microplankton was highest in August and September while in 2015 the opposite trend was observed where the relative importance of microplankton decreased in August and September 2015 relative to June and July. In 2014 in Revelstoke Reservoir, the size structure of primary productivity differed between Revelstoke Middle and Revelstoke Forebay. At Revelstoke Middle, picoplankton and nanoplankton both accounted for ~40% of total productivity while microplankton production accounted for 19% (Figure 7). This is in contrast to the size structure measured at Revelstoke Forebay which more closely resembled the size structure of Kinbasket Reservoir where nanoplankton was the most productive fraction followed by picoplankton and then microplankton. Unlike the size structure measured in 2014, in 2015 in Revelstoke Reservoir the size structure of primary productivity was similar between Revelstoke Middle and Revelstoke Forebay. At both stations, picoplankton was the most productive fraction followed by nanoplankton and the least productive fraction was microplankton.

From 2009-2011 the relative importance of picoplankton production was increasing (Harris, 2014) along with a decrease in the relative importance of the larger fractions, nanoplankton and microplankton (Figure 8). This implied the reservoir was still in a state of deceasing productivity or oligotrophication. In 2012 this trend was reversed where the relative contribution of production accounted for by phytoplankton cells less than 20.0 µm increased from 2013 to 2015 due to increased nanoplankton production. Also starting in 2012, microplankton production has declined during each study year to the lowest level measured in the time series (Figure 8).

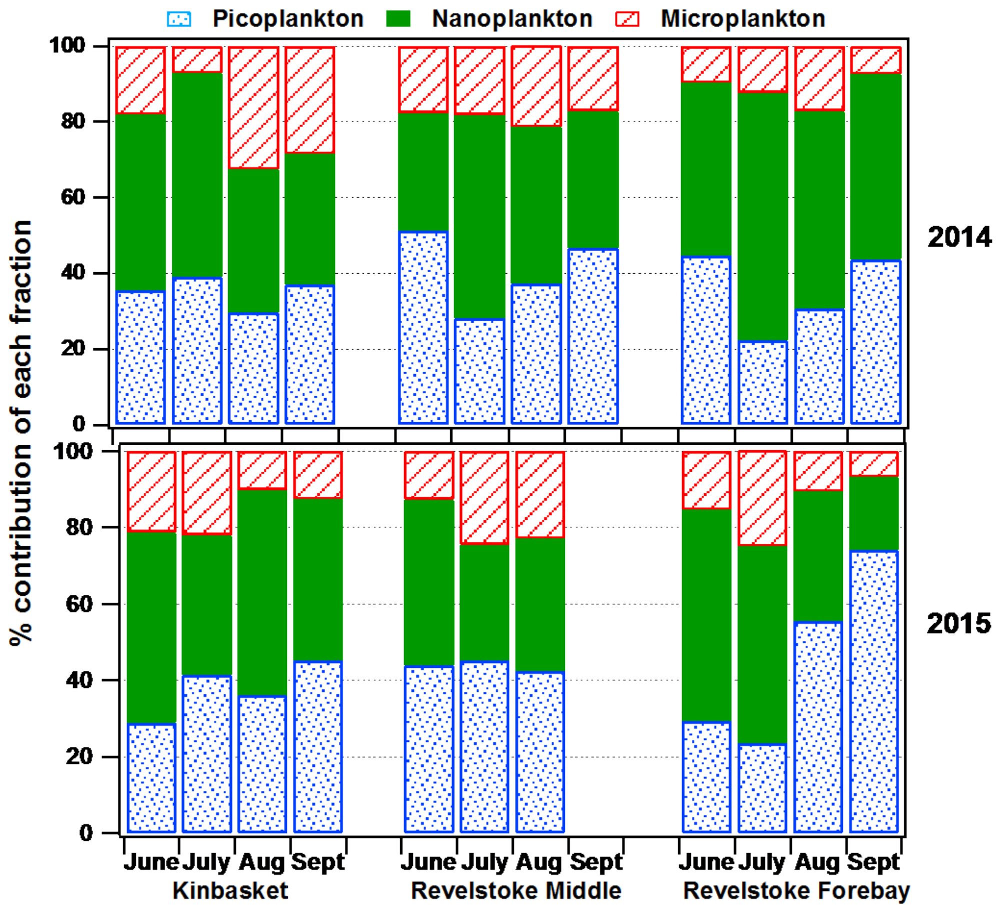


Figure 7 Relative contribution of picoplankton (0.2-2 µm), nanoplankton (2-20 µm), and microplankton (>20 µm) to primary productivity in Kinbasket and Revelstoke in 2014 and 2015.

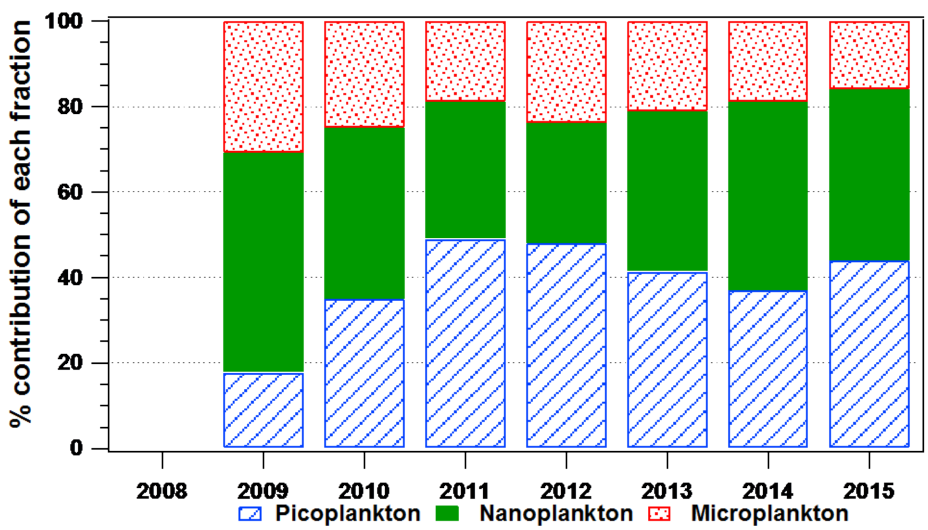


Figure 8 Mean annual size structure of primary productivity in Kinbasket and Revelstoke in 2009-2015. Note: monthly means for Kinbasket and Revelstoke were averaged.

Discussion

The food web in aquatic ecosystems is influenced by a number of complex factors including lake geomorphology, climatology based on its location, and a diverse range of physical and chemical parameters such as light, temperature, flow, and nutrients. In addition, human interactions have influenced the functional relationships and productivity of aquatic ecosystems. It is important that we characterize the current state of the aquatic ecosystem in order to gain an understanding of how the ecosystem dynamics are controlled and how the aquatic ecosystem responds to these diverse factors including hydroelectric reservoir operations. This increased understanding of the functional dynamics of the reservoir will advance our knowledge which in turn will allow water managers to predict ecosystem responses to future operational changes. This report summaries data collected on the base of the food chain, the phytoplankton community, which is just one component of the much larger monitoring program that encompasses physical flow dynamics and chemical dynamics. Ultimately, the integration of the findings from each component of the monitoring program will lead to a comprehensive understanding of the limnology of Kinbasket and Revelstoke Reservoirs.

Primary productivity sets the upper threshold for productivity at upper trophic levels. The results of this study confirm earlier findings of low phytoplankton biomass of ~30 mg/m^2 in Kinbasket and ~15 mg/m^2 in Revelstoke and low rates of primary productivity of ~150 mg C/m^2/d in Kinbasket and ~100 mg C/m^2/d in Revelstoke. Both parameters in this study (chlorophyll and primary productivity) fall within the general ranges of oligotrophic trophic category as defined by Wetzel, 2001.

An extremely low percentage of energy is transferred from one trophic level to the next, between 5-15%, so the number of trophic levels in a food chain is an important determinant of productivity of upper trophic levels (Wetzel, 2001). The size structure of the phytoplankton community can provide some insight into the structure of the food web. Nanoplankton (2.0-20.0 µm) are effectively consumed by many zooplankton species which is important for the efficient transfer of organic matter up the food chain and the high contribution of nanoplankton suggests a strong linkage from this trophic level to the microzooplankton trophic level. While nanoplankton biomass and production are high in both Kinbasket and Revelstoke and often dominate the phytoplankton community, the strong prevalence of picoplankton size cells suggests the microbial food web is also important in both Kinbasket and Revelstoke Reservoirs. The microbial food web or microbial loop likely support an important function in providing a pathway for small cells to be incorporated into the food web and, equally important, the microbial loop may play an important role in efficient nutrient recycling (Stockner and Porter, 1988)

The size structure also provides some clues as to the nutrient dynamics of Kinbasket and Revelstoke. Small cells often dominate in oligotrophic waters as their large surface area to volume ratio supports efficient uptake of growth rates of small cells. On the other hand large cells often dominate in nutrient rich eutrophic conditions due to the large uptake kinetics and large storage vacuoles of large microplankton sized cells. The prevalence of small cells and the low contribution of large cells in Kinbasket and Revelstoke suggest that nutrient availability is low and the microbial loop likely plays an important role in nutrient recycling in these large oligotrophic reservoirs.

This study confirms the low productivity status of Kinbasket and Revelstoke Reservoirs and provides a clearer understanding of the size structure of the phytoplankton communities which will aid in our understanding of trophic web dynamics and the sustainability of the fish communities.

Table 2 Depth integrated chlorophyll *a* and daily primary productivity for Kinbasket and Revelstoke reservoirs in BC in 2014 and 2015.

	StudyYear	Chlorophyll *a* ($mg\ m^{-2}$)	Primary Productivity ($mg\ C\ m^{-2}\ d^{-1}$)
Kinbasket Forebay	2014	28.9	150.9
Revelstoke Middle	2014	12.8	118.0
Revelstoke Forebay	2014	17.3	125.0
Kinbasket Forebay	2015	28.6	152.5
Revelstoke Middle	2015	16.4	81.0
Revelstoke Forebay	2015	14.6	161.2
Kinbasket Forebay	Mean	28.8	151.7
Revelstoke Middle	Mean	14.6	99.5
Revelstoke Forebay	Mean	15.9	109.6

Literature Cited

BC Hydro. 2007. CLBMON-3 Kinbasket and Revelstoke Reservoirs Ecological Productivity Monitoring Terms of Reference. BC Hydro dated October 24, 2007.

Harris, S.L. 2012. Primary productivity in Kinbasket and Revelstoke Reservoirs, 2010. Report prepared for BC Hydro. 21p

Harris, S.L. 2014. Primary productivity in Kinbasket and Revelstoke Reservoirs, 2012. Report prepared for BC Hydro. 19p

Harris, S.L. 2016. Primary productivity in Kinbasket and Revelstoke Reservoirs, 2013. Report prepared for BC Hydro. 27p

Stockner. J.G and K.G Porter. 1988 Microbial foodwebs in freshwater planktonic ecosystems. In: Carpenter, S. [ed.], Complex interactions in lake communities. Springer-Verlag New York,. Inc. 283 p

Wetzel, R.G. 2001. Limnology. 3rd Ed, Academic Press, San Diego.

Appendix A Field observations and incubation information for the 2014 & 2015 primary productivity study. Stations are: KB = Kinbasket-Forebay, RM = Revelstoke-Middle (also called Downie), RF = Revelstoke-Forebay.

Date	**Stn**	**Weather**	**Inc. Start**	**Inc. End**	**Total Inc Time (hr.min)**
24-Jun-14	RF	overcast with sunny breaks	8:50	12:50	4.00
25-Jun-14	KB	mixed sun and cloud	8:30	12:30	4.00
26-Jun-14	RM	sun with a few clouds	8:40	12:48	4.03
22-Jul-14	RF	overcast, calm	11:35	15:38	4.05
23-Jul-14	KB	mainly cloud, light air	8:04	12:04	4.00
24-Jul-14	RM	overcast, light breeze (thunder showers w high wind night before)	8:40	12:40	4.00
19-Aug-14	RF	overcast, light rain, light breeze (thunder showers night before)	8:45	12:45	4.00
20-Aug-14	KB	sun with some clouds, gentle breeze	8:45	12:45	4.00
21-Aug-14	RM	mixed sun and cloud, light breeze	8:35	12:35	4.00
23-Sep-14	RF	overcast, calm (thunder and heavy rain night before)	9:05	12:15	3.17
24-Sep-14	KB	overcast, fog, light rain, wind light air to gentle breeze	8:40	12:40	4.00
25-Sep-14	RM	overcast, light fog, light rain, calm to light breeze	8:25	12:25	4.00
23-Jun-15	RF	Overcast (85% cc), light air	9:15	13:25	4.17
24-Jun-15	KB	Mainly clear/sun (10% cc), light air	8:43	12:46	4.05
25-Jun-15	RM	Mainly clear/sun (5% cc), light air	8:41	12:42	4.02
22-Jul-15	RF	Partly cloudy (20% cc increased to 70% cc), gentle to moderate breeze	9:14	13:30	3.88
23-Jul-15	KB	Overcast (100% cc), gentle breeze	8:43	12:50	4.12
24-Jul-15	RM	Mainly clear/sun (35% cc), clam, water murky	8:05	12:05	4.00
25-Aug-15	RM	Clear/sun (0% cc), calm, very hazy (smoke)	9:24	13:25	4.00
26-Aug-15	KB	Mainly clear/sun (10% cc), variable wind (light to moderate breeze)	8:15	12:15	4.00
27-Aug-15	RF	Mainly clear/sun (10% cc), very hazy (smoke), light breeze	8:45	12:45	4.02
22-Sep-15	KB	Overcast (100% cc to 70% cc), fog, light breeze	8:30	12:40	4.17
23-Sep-15	RM	Overcast (90% cc), calm	8:21	12:21	4.00
24-Sep-15	RF	Overcast (80% cc), calm to light breeze	8:44	12:45	4.02

Appendix B Raw Chlorophyll and Primary Productivity

Table B1 Raw chlorophyll and primary productivity data for 2014 & 2015.

Station	Date	Depth (m)	Filter Size (µm)	Chl (mg/m^3)	PP (mg $C/m^3/h$)	PP (mg $C/m^3/day$)
KIN	25-Jun-14	0	I-0.2	2.43	1.09	9.02
KIN	25-Jun-14	1	I-0.2	2.15	0.87	7.25
KIN	25-Jun-14	2	I-0.2	2.24	1.08	8.98
KIN	25-Jun-14	5	I-0.2	2.20	1.27	10.54
KIN	25-Jun-14	10	I-0.2	2.17	0.89	7.36
KIN	25-Jun-14	15	I-0.2	1.25	0.15	1.24
KIN	25-Jun-14	0	I-2.0	1.23	0.41	1.27
KIN	25-Jun-14	1	I-2.0	1.40	0.52	4.27
KIN	25-Jun-14	2	I-2.0	1.39	0.76	6.29
KIN	25-Jun-14	5	I-2.0	1.43	0.83	6.85
KIN	25-Jun-14	10	I-2.0	1.35	0.58	4.80
KIN	25-Jun-14	15	I-2.0	0.58	0.09	0.76
KIN	25-Jun-14	0	I-20.0	0.24	0.15	1.27
KIN	25-Jun-14	1	I-20.0	0.23	0.17	1.38
KIN	25-Jun-14	2	I-20.0	0.24	0.20	1.62
KIN	25-Jun-14	5	I-20.0	0.24	0.20	1.63
KIN	25-Jun-14	10	I-20.0	0.22	0.20	1.62
KIN	25-Jun-14	15	I-20.0	0.12	0.03	0.21
KIN	23-Jul-14	0	I-0.2	1.08	0.66	6.02
KIN	23-Jul-14	1	I-0.2	1.58	0.88	8.06
KIN	23-Jul-14	2	I-0.2	1.49	0.78	7.08
KIN	23-Jul-14	5	I-0.2	1.81	1.42	12.94
KIN	23-Jul-14	10	I-0.2	2.39	0.48	4.34
KIN	23-Jul-14	0	I-2.0	0.70	0.33	3.05
KIN	23-Jul-14	1	I-2.0	0.70	0.73	6.64
KIN	23-Jul-14	2	I-2.0	1.24	0.59	5.39
KIN	23-Jul-14	5	I-2.0	0.89	0.73	6.65
KIN	23-Jul-14	10	I-2.0	0.58	0.35	3.23
KIN	23-Jul-14	0	I-20.0	0.07	0.06	0.54
KIN	23-Jul-14	1	I-20.0	0.12	0.09	0.83
KIN	23-Jul-14	2	I-20.0	0.07	0.10	0.93
KIN	23-Jul-14	5	I-20.0	0.08	0.09	0.79
KIN	23-Jul-14	10	I-20.0	0.14	0.01	0.09
KIN	20-Aug-14	0	I-0.2	1.40	0.71	4.69
KIN	20-Aug-14	1	I-0.2	1.38	0.93	6.20
KIN	20-Aug-14	2	I-0.2	0.98	0.91	6.06
KIN	20-Aug-14	5	I-0.2	1.30	1.33	8.83
KIN	20-Aug-14	10	I-0.2	1.37	0.94	6.23
KIN	20-Aug-14	15	I-0.2	1.98	0.33	2.20
KIN	20-Aug-14	17	I-0.2	1.54	0.38	2.49
KIN	20-Aug-14	0	I-2.0	0.99	0.41	2.73
KIN	20-Aug-14	1	I-2.0	0.96	0.67	4.43
KIN	20-Aug-14	2	I-2.0	0.85	0.65	4.32

Station	Date	Depth (m)	Filter Size (μm)	Chl (mg/m^3)	PP (mg $C/m^3/h$)	PP (mg $C/m^3/day$)
KIN	20-Aug-14	5	I-2.0	1.04	0.90	5.98
KIN	20-Aug-14	10	I-2.0	1.12	0.67	4.46
KIN	20-Aug-14	15	I-2.0	1.27	0.28	1.87
KIN	20-Aug-14	17	I-2.0	1.21	0.21	1.36
KIN	20-Aug-14	0	I-20.0	0.26	0.19	1.25
KIN	20-Aug-14	1	I-20.0	0.25	0.32	2.12
KIN	20-Aug-14	2	I-20.0	0.25	0.34	2.28
KIN	20-Aug-14	5	I-20.0	0.32	0.48	3.20
KIN	20-Aug-14	10	I-20.0	0.30	0.27	1.82
KIN	20-Aug-14	15	I-20.0	0.28	0.09	0.61
KIN	20-Aug-14	17	I-20.0	0.25	0.07	0.47
KIN	24-Sep-14	0	I-0.2	2.03	0.48	28.67
KIN	24-Sep-14	1	I-0.2	1.89	0.42	25.04
KIN	24-Sep-14	2	I-0.2	1.94	0.53	31.73
KIN	24-Sep-14	5	I-0.2	1.82	0.33	19.53
KIN	24-Sep-14	10	I-0.2	2.02	0.19	11.37
KIN	24-Sep-14	15	I-0.2	1.70	0.04	2.52
KIN	24-Sep-14	20	I-0.2	0.79	0.08	4.70
KIN	24-Sep-14	0	I-2.0	1.49	0.39	23.39
KIN	24-Sep-14	1	I-2.0	1.35	0.32	18.92
KIN	24-Sep-14	2	I-2.0	1.40	0.34	20.67
KIN	24-Sep-14	5	I-2.0	1.38	0.23	13.81
KIN	24-Sep-14	10	I-2.0	1.39	0.09	5.11
KIN	24-Sep-14	15	I-2.0	1.30	0.04	2.38
KIN	24-Sep-14	20	I-2.0	0.61	0.01	0.34
KIN	24-Sep-14	0	I-20.0	0.66	0.19	11.24
KIN	24-Sep-14	1	I-20.0	0.47	0.14	8.31
KIN	24-Sep-14	2	I-20.0	0.62	0.17	10.40
KIN	24-Sep-14	5	I-20.0	0.55	0.12	6.96
KIN	24-Sep-14	10	I-20.0	0.63	0.03	1.59
KIN	24-Sep-14	15	I-20.0	0.55	0.01	0.89
KIN	24-Sep-14	20	I-20.0	0.22	0.00	0.05
KIN	24-Jun-15	0	I-0.2	1.24	0.32	2.35
KIN	24-Jun-15	1	I-0.2	1.31	0.46	3.37
KIN	24-Jun-15	2	I-0.2	1.14	0.35	2.59
KIN	24-Jun-15	5	I-0.2	1.55	0.49	3.62
KIN	24-Jun-15	10	I-0.2	1.96	0.39	2.86
KIN	24-Jun-15	15	I-0.2	2.08	0.35	2.54
KIN	24-Jun-15	18	I-0.2	0.76	0.16	1.21
KIN	24-Jun-15	0	I-2.0	0.74	0.20	1.44
KIN	24-Jun-15	1	I-2.0	0.74	0.22	1.61
KIN	24-Jun-15	2	I-2.0	0.69	0.31	2.26
KIN	24-Jun-15	5	I-2.0	0.74	0.33	2.45
KIN	24-Jun-15	10	I-2.0	1.05	0.33	2.40
KIN	24-Jun-15	15	I-2.0	1.07	0.22	1.63
KIN	24-Jun-15	18	I-2.0	0.55	0.06	0.47
KIN	24-Jun-15	0	I-20.0	0.15	0.04	0.32
KIN	24-Jun-15	1	I-20.0	0.12	0.10	0.73

Station	Date	Depth (m)	Filter Size (µm)	Chl (mg/m^3)	PP (mg $C/m^3/h$)	PP (mg $C/m^3/day$)
KIN	24-Jun-15	2	I-20.0	0.15	0.10	0.73
KIN	24-Jun-15	5	I-20.0	0.14	0.11	0.84
KIN	24-Jun-15	10	I-20.0	0.15	0.09	0.64
KIN	24-Jun-15	15	I-20.0	0.16	0.06	0.43
KIN	24-Jun-15	18	I-20.0	0.07	0.02	0.13
KIN	23-Jul-15	0	I-0.2	1.74	0.93	15.11
KIN	23-Jul-15	1	I-0.2	1.71	0.81	13.25
KIN	23-Jul-15	2	I-0.2	1.63	1.00	16.37
KIN	23-Jul-15	5	I-0.2	1.56	0.74	12.05
KIN	23-Jul-15	10	I-0.2	2.46	0.73	11.88
KIN	23-Jul-15	15	I-0.2	1.62	0.40	6.47
KIN	23-Jul-15	18	I-0.2	1.31	0.14	2.26
KIN	23-Jul-15	0	I-2.0	1.04	0.57	9.36
KIN	23-Jul-15	1	I-2.0	1.08	0.40	6.53
KIN	23-Jul-15	2	I-2.0	0.98	0.64	10.47
KIN	23-Jul-15	5	I-2.0	0.88	0.59	9.68
KIN	23-Jul-15	10	I-2.0	1.49	0.41	6.63
KIN	23-Jul-15	15	I-2.0	1.12	0.12	1.98
KIN	23-Jul-15	18	I-2.0	0.81	0.00	0.00
KIN	23-Jul-15	0	I-20.0	0.16	0.23	3.75
KIN	23-Jul-15	1	I-20.0	0.16	0.24	3.94
KIN	23-Jul-15	2	I-20.0	0.16	0.20	3.19
KIN	23-Jul-15	5	I-20.0	0.15	0.24	3.96
KIN	23-Jul-15	10	I-20.0	0.21	0.12	2.02
KIN	23-Jul-15	15	I-20.0	0.16	0.06	0.99
KIN	23-Jul-15	18	I-20.0	0.11	0.00	0.00
KIN	26-Aug-15	0	I-0.2	1.62	1.19	18.16
KIN	26-Aug-15	1	I-0.2	1.31	1.01	15.30
KIN	26-Aug-15	2	I-0.2	1.28	0.74	11.24
KIN	26-Aug-15	5	I-0.2	1.40	0.68	10.27
KIN	26-Aug-15	10	I-0.2	1.52	0.67	10.15
KIN	26-Aug-15	15	I-0.2	1.53	0.62	9.41
KIN	26-Aug-15	20	I-0.2	1.12	0.15	2.30
KIN	26-Aug-15	0	I-2.0	0.75	0.55	8.34
KIN	26-Aug-15	1	I-2.0	0.77	0.64	9.80
KIN	26-Aug-15	2	I-2.0	0.72	0.55	8.34
KIN	26-Aug-15	5	I-2.0	0.64	0.57	8.61
KIN	26-Aug-15	10	I-2.0	0.82	0.42	6.38
KIN	26-Aug-15	15	I-2.0	1.03	0.29	4.41
KIN	26-Aug-15	20	I-2.0	0.75	0.09	1.40
KIN	26-Aug-15	0	I-20.0	0.07	0.08	1.18
KIN	26-Aug-15	1	I-20.0	0.06	0.10	1.46
KIN	26-Aug-15	2	I-20.0	0.07	0.04	0.54
KIN	26-Aug-15	5	I-20.0	0.06	0.10	1.47
KIN	26-Aug-15	10	I-20.0	0.07	0.07	1.11
KIN	26-Aug-15	15	I-20.0	0.10	0.06	0.86
KIN	26-Aug-15	20	I-20.0	0.09	0.02	0.33
KIN	22-Sep-15	0	I-0.2	1.27	0.58	5.78

Station	Date	Depth (m)	Filter Size (μm)	Chl (mg/m^3)	PP ($mg C/m^3/h$)	PP ($mg C/m^3/day$)
KIN	22-Sep-15	1	I-0.2	1.23	2.08	20.71
KIN	22-Sep-15	2	I-0.2	1.23	2.54	25.29
KIN	22-Sep-15	5	I-0.2	1.28	1.48	14.69
KIN	22-Sep-15	10	I-0.2	1.22	0.39	3.91
KIN	22-Sep-15	15	I-0.2	1.07	0.19	1.93
KIN	22-Sep-15	20	I-0.2	1.09	0.62	6.21
KIN	22-Sep-15	0	I-2.0	0.73	0.27	2.68
KIN	22-Sep-15	1	I-2.0	0.65	0.72	7.17
KIN	22-Sep-15	2	I-2.0	0.67	0.80	7.95
KIN	22-Sep-15	5	I-2.0	0.54	0.87	8.66
KIN	22-Sep-15	10	I-2.0	0.54	0.53	5.28
KIN	22-Sep-15	15	I-2.0	0.58	0.33	3.28
KIN	22-Sep-15	20	I-2.0	0.60	0.12	1.17
KIN	22-Sep-15	0	I-20.0	0.07	0.15	1.51
KIN	22-Sep-15	1	I-20.0	0.07	0.11	1.13
KIN	22-Sep-15	2	I-20.0	0.07	0.16	1.60
KIN	22-Sep-15	5	I-20.0	0.05	0.20	2.03
KIN	22-Sep-15	10	I-20.0	0.06	0.13	1.31
KIN	22-Sep-15	15	I-20.0	0.07	0.08	0.76
KIN	22-Sep-15	20	I-20.0	0.07	0.03	0.26
REV-FB	24-Jun-14	0	I-0.2	1.22	1.24	9.04
REV-FB	24-Jun-14	1	I-0.2	1.15	0.88	6.42
REV-FB	24-Jun-14	2	I-0.2	1.15	1.00	7.32
REV-FB	24-Jun-14	5	I-0.2	1.13	0.66	4.83
REV-FB	24-Jun-14	10	I-0.2	1.45	0.22	1.58
REV-FB	24-Jun-14	15	I-0.2	1.17	0.12	0.85
REV-FB	24-Jun-14	0	I-2.0	0.65	0.74	5.37
REV-FB	24-Jun-14	1	I-2.0	0.64	0.58	4.23
REV-FB	24-Jun-14	2	I-2.0	0.65	0.55	4.04
REV-FB	24-Jun-14	5	I-2.0	0.64	0.37	2.71
REV-FB	24-Jun-14	10	I-2.0	0.81	0.12	0.87
REV-FB	24-Jun-14	15	I-2.0	0.69	0.01	0.10
REV-FB	24-Jun-14	0	I-20.0		0.16	1.19
REV-FB	24-Jun-14	1	I-20.0		0.17	1.25
REV-FB	24-Jun-14	2	I-20.0		0.14	0.99
REV-FB	24-Jun-14	5	I-20.0		0.04	0.27
REV-FB	24-Jun-14	10	I-20.0		0.01	0.04
REV-FB	24-Jun-14	15	I-20.0		0.01	0.10
REV-FB	22-Jul-14	0	I-0.2	0.67	0.66	10.49
REV-FB	22-Jul-14	1	I-0.2	0.67	1.09	17.36
REV-FB	22-Jul-14	2	I-0.2	0.39	1.20	19.01
REV-FB	22-Jul-14	5	I-0.2	0.78	1.27	20.21
REV-FB	22-Jul-14	10	I-0.2	1.66	0.52	8.28
REV-FB	22-Jul-14	15	I-0.2	0.91	0.09	1.49
REV-FB	22-Jul-14	0	I-2.0	0.34	0.64	10.10
REV-FB	22-Jul-14	1	I-2.0	0.37	0.87	13.88
REV-FB	22-Jul-14	2	I-2.0	0.34	1.04	16.58
REV-FB	22-Jul-14	5	I-2.0	0.38	0.86	13.74

Station	Date	Depth (m)	Filter Size (μm)	Chl (mg/m^3)	PP (mg $C/m^3/h$)	PP (mg $C/m^3/day$)
REV-FB	22-Jul-14	10	I-2.0	0.83	0.45	7.08
REV-FB	22-Jul-14	15	I-2.0	0.71	0.07	1.10
REV-FB	22-Jul-14	0	I-20.0	0.10	0.13	2.02
REV-FB	22-Jul-14	1	I-20.0	0.07	0.15	2.39
REV-FB	22-Jul-14	2	I-20.0	0.07	0.17	2.71
REV-FB	22-Jul-14	5	I-20.0	0.06	0.14	2.27
REV-FB	22-Jul-14	10	I-20.0	0.08	0.06	1.01
REV-FB	22-Jul-14	15	I-20.0	0.08	0.01	0.16
REV-FB	19-Aug-14	0	I-0.2	1.11	1.16	14.23
REV-FB	19-Aug-14	1	I-0.2	0.95	1.00	12.26
REV-FB	19-Aug-14	2	I-0.2	0.94	1.25	15.29
REV-FB	19-Aug-14	5	I-0.2	1.10	1.02	12.46
REV-FB	19-Aug-14	10	I-0.2	1.38	0.39	4.74
REV-FB	19-Aug-14	15	I-0.2	1.29	0.08	0.96
REV-FB	19-Aug-14	0	I-2.0	0.64	0.78	9.53
REV-FB	19-Aug-14	1	I-2.0	0.66	0.79	9.61
REV-FB	19-Aug-14	2	I-2.0	0.58	0.93	11.39
REV-FB	19-Aug-14	5	I-2.0	0.64	0.80	9.84
REV-FB	19-Aug-14	10	I-2.0	0.92	0.16	1.94
REV-FB	19-Aug-14	15	I-2.0	0.65	0.04	0.53
REV-FB	19-Aug-14	0	I-20.0	0.09	0.14	1.68
REV-FB	19-Aug-14	1	I-20.0	0.09	0.19	2.28
REV-FB	19-Aug-14	2	I-20.0	0.08	0.18	2.16
REV-FB	19-Aug-14	5	I-20.0	0.10	0.22	2.64
REV-FB	19-Aug-14	10	I-20.0	0.12	0.06	0.73
REV-FB	19-Aug-14	15	I-20.0	0.14	0.01	0.12
REV-FB	23-Sep-14	0	I-0.2	1.16	0.55	7.45
REV-FB	23-Sep-14	1	I-0.2	1.09	0.70	9.55
REV-FB	23-Sep-14	2	I-0.2	1.02	1.06	14.46
REV-FB	23-Sep-14	5	I-0.2	1.05	0.85	11.49
REV-FB	23-Sep-14	10	I-0.2	1.10	0.01	0.18
REV-FB	23-Sep-14	15	I-0.2	0.87	0.37	5.00
REV-FB	23-Sep-14	22	I-0.2	0.36	0.28	3.81
REV-FB	23-Sep-14	0	I-2.0	0.44	0.56	7.63
REV-FB	23-Sep-14	1	I-2.0	0.41	0.39	5.27
REV-FB	23-Sep-14	2	I-2.0	0.40	0.59	8.05
REV-FB	23-Sep-14	5	I-2.0	0.41	0.48	6.56
REV-FB	23-Sep-14	10	I-2.0	0.40	0.24	3.22
REV-FB	23-Sep-14	15	I-2.0	0.35	0.18	2.40
REV-FB	23-Sep-14	22	I-2.0	0.30	0.03	0.38
REV-FB	23-Sep-14	0	I-20.0	0.06	0.05	0.68
REV-FB	23-Sep-14	1	I-20.0	0.06	0.04	0.60
REV-FB	23-Sep-14	2	I-20.0	0.05	0.08	1.11
REV-FB	23-Sep-14	5	I-20.0	0.04	0.08	1.09
REV-FB	23-Sep-14	10	I-20.0	0.06	0.03	0.40
REV-FB	23-Sep-14	15	I-20.0	0.05	0.02	0.24
REV-FB	23-Sep-14	22	I-20.0	0.06	0.00	0.03
REV-FB	23-Jun-15	0	I-0.2	0.74	0.22	1.64

Station	Date	Depth (m)	Filter Size (µm)	Chl (mg/m^3)	PP (mg C/m^3/h)	PP (mg C/m^3/day)
REV-FB	23-Jun-15	1	I-0.2	0.74	0.27	2.01
REV-FB	23-Jun-15	2	I-0.2	0.68	0.25	1.82
REV-FB	23-Jun-15	5	I-0.2	0.89	0.26	1.89
REV-FB	23-Jun-15	10	I-0.2	1.12	0.18	1.29
REV-FB	23-Jun-15	15	I-0.2	0.45	0.04	0.29
REV-FB	23-Jun-15	0	I-2.0	0.34	0.17	1.25
REV-FB	23-Jun-15	1	I-2.0	0.35	0.17	1.24
REV-FB	23-Jun-15	2	I-2.0	0.34	0.20	1.51
REV-FB	23-Jun-15	5	I-2.0	0.37	0.19	1.38
REV-FB	23-Jun-15	10	I-2.0	0.46	0.11	0.80
REV-FB	23-Jun-15	15	I-2.0	0.31	0.03	0.23
REV-FB	23-Jun-15	0	I-20.0	0.04	0.03	0.21
REV-FB	23-Jun-15	1	I-20.0	0.04	0.04	0.28
REV-FB	23-Jun-15	2	I-20.0	0.04	0.04	0.33
REV-FB	23-Jun-15	5	I-20.0	0.05	0.04	0.32
REV-FB	23-Jun-15	10	I-20.0	0.06	0.02	0.18
REV-FB	23-Jun-15	15	I-20.0	0.04	0.00	0.04
REV-FB	22-Jul-15	0	I-0.2	1.40	0.56	7.24
REV-FB	22-Jul-15	1	I-0.2	1.37	0.75	9.74
REV-FB	22-Jul-15	2	I-0.2	1.42	1.06	13.67
REV-FB	22-Jul-15	5	I-0.2	1.33	0.88	11.36
REV-FB	22-Jul-15	10	I-0.2	1.56	0.57	7.34
REV-FB	22-Jul-15	15	I-0.2	0.72	0.11	1.48
REV-FB	22-Jul-15	0	I-2.0	0.80	0.60	7.78
REV-FB	22-Jul-15	1	I-2.0	0.82	0.67	8.73
REV-FB	22-Jul-15	2	I-2.0	0.85	0.72	9.32
REV-FB	22-Jul-15	5	I-2.0	0.85	0.77	9.93
REV-FB	22-Jul-15	10	I-2.0	0.91	0.37	4.75
REV-FB	22-Jul-15	15	I-2.0	0.40	0.07	0.94
REV-FB	22-Jul-15	0	I-20.0	0.23	0.18	2.37
REV-FB	22-Jul-15	1	I-20.0	0.22	0.22	2.79
REV-FB	22-Jul-15	2	I-20.0	0.22	0.27	3.50
REV-FB	22-Jul-15	5	I-20.0	0.20	0.28	3.57
REV-FB	22-Jul-15	10	I-20.0	0.26	0.09	1.21
REV-FB	22-Jul-15	15	I-20.0	0.11	0.01	0.18
REV-FB	27-Aug-15	0	I-0.2	0.80	0.88	12.61
REV-FB	27-Aug-15	1	I-0.2	0.93	0.90	12.77
REV-FB	27-Aug-15	2	I-0.2	0.84	1.17	16.63
REV-FB	27-Aug-15	5	I-0.2	0.88	1.00	14.24
REV-FB	27-Aug-15	10	I-0.2	0.88	0.39	5.61
REV-FB	27-Aug-15	12	I-0.2	0.77	0.44	6.28
REV-FB	27-Aug-15	0	I-2.0	0.48	0.31	4.45
REV-FB	27-Aug-15	1	I-2.0	0.54	0.44	6.32
REV-FB	27-Aug-15	2	I-2.0	0.50	0.38	5.49
REV-FB	27-Aug-15	5	I-2.0	0.49	0.54	7.76
REV-FB	27-Aug-15	10	I-2.0	0.49	0.15	2.08
REV-FB	27-Aug-15	12	I-2.0	0.35	0.16	2.30
REV-FB	27-Aug-15	0	I-20.0	0.09	0.13	1.81

Station	Date	Depth (m)	Filter Size (μm)	Chl (mg/m^3)	PP ($mg C/m^3/h$)	PP ($mg C/m^3/day$)
REV-FB	27-Aug-15	1	I-20.0	0.07	0.13	1.81
REV-FB	27-Aug-15	2	I-20.0	0.09	0.00	0.06
REV-FB	27-Aug-15	5	I-20.0	0.10	0.15	2.12
REV-FB	27-Aug-15	10	I-20.0	0.08	0.05	0.75
REV-FB	27-Aug-15	12	I-20.0	0.11	0.04	0.52
REV-FB	24-Sep-15	0	I-0.2	1.24	2.73	51.94
REV-FB	24-Sep-15	1	I-0.2	1.29	1.66	31.54
REV-FB	24-Sep-15	2	I-0.2	1.15	2.69	51.30
REV-FB	24-Sep-15	5	I-0.2	0.82	1.88	35.79
REV-FB	24-Sep-15	10	I-0.2	1.00	0.11	2.17
REV-FB	24-Sep-15	15	I-0.2	0.54	0.43	8.21
REV-FB	24-Sep-15	20	I-0.2	0.51	0.14	2.64
REV-FB	24-Sep-15	0	I-2.0	0.63	0.50	9.53
REV-FB	24-Sep-15	1	I-2.0	0.58	0.44	8.32
REV-FB	24-Sep-15	2	I-2.0	0.71	0.54	10.35
REV-FB	24-Sep-15	5	I-2.0	0.63	0.56	10.72
REV-FB	24-Sep-15	10	I-2.0	0.52	0.19	3.59
REV-FB	24-Sep-15	15	I-2.0	0.46	0.01	0.11
REV-FB	24-Sep-15	20	I-2.0	0.38	0.02	0.33
REV-FB	24-Sep-15	0	I-20.0	0.16	0.07	1.39
REV-FB	24-Sep-15	1	I-20.0	0.15	0.15	2.91
REV-FB	24-Sep-15	2	I-20.0	0.14	0.13	2.56
REV-FB	24-Sep-15	5	I-20.0	0.10	0.14	2.59
REV-FB	24-Sep-15	10	I-20.0	0.09	0.06	1.18
REV-FB	24-Sep-15	15	I-20.0	0.07	0.00	0.08
REV-FB	24-Sep-15	20	I-20.0	0.07	0.00	0.04
REV-Mid	26-Jun-14	0	I-0.2	0.87	0.53	12.60
REV-Mid	26-Jun-14	1	I-0.2	0.75	0.47	11.21
REV-Mid	26-Jun-14	2	I-0.2	0.80	0.52	12.37
REV-Mid	26-Jun-14	5	I-0.2	1.51	0.60	14.23
REV-Mid	26-Jun-14	10	I-0.2	1.47	0.24	5.74
REV-Mid	26-Jun-14	12	I-0.2	0.70	0.16	3.77
REV-Mid	26-Jun-14	0	I-2.0	0.30	0.24	5.77
REV-Mid	26-Jun-14	1	I-2.0	0.28	0.22	5.13
REV-Mid	26-Jun-14	2	I-2.0	0.30	0.24	5.68
REV-Mid	26-Jun-14	5	I-2.0	0.70	0.30	7.22
REV-Mid	26-Jun-14	10	I-2.0	1.01	0.13	3.04
REV-Mid	26-Jun-14	12	I-2.0	0.40	0.02	0.56
REV-Mid	26-Jun-14	0	I-20.0	0.03	0.02	0.52
REV-Mid	26-Jun-14	1	I-20.0	0.03	0.04	0.86
REV-Mid	26-Jun-14	2	I-20.0	0.11	0.25	5.89
REV-Mid	26-Jun-14	5	I-20.0	0.11	0.08	1.88
REV-Mid	26-Jun-14	10	I-20.0	0.03	0.03	0.73
REV-Mid	26-Jun-14	12	I-20.0	0.06	0.00	0.00
REV-Mid	24-Jul-14	0	I-0.2	1.22		
REV-Mid	24-Jul-14	1	I-0.2	1.48	1.16	23.51
REV-Mid	24-Jul-14	2	I-0.2	1.23	1.01	20.46
REV-Mid	24-Jul-14	5	I-0.2	1.04	0.24	4.95

Station	Date	Depth (m)	Filter Size (μm)	Chl (mg/m^3)	PP ($mg C/m^3/h$)	PP ($mg C/m^3/day$)
REV-Mid	24-Jul-14	10	I-0.2	0.84	0.03	0.66
REV-Mid	24-Jul-14	0	I-2.0	0.75		
REV-Mid	24-Jul-14	1	I-2.0	0.70	0.74	14.97
REV-Mid	24-Jul-14	2	I-2.0	1.52	0.68	13.70
REV-Mid	24-Jul-14	5	I-2.0	0.26	0.26	5.19
REV-Mid	24-Jul-14	10	I-2.0	0.22	0.00	0.07
REV-Mid	24-Jul-14	0	I-20.0	0.08		
REV-Mid	24-Jul-14	1	I-20.0	0.08	0.18	3.55
REV-Mid	24-Jul-14	2	I-20.0	0.07	0.14	2.82
REV-Mid	24-Jul-14	5	I-20.0	0.09	0.08	1.69
REV-Mid	24-Jul-14	10	I-20.0	0.13	0.01	0.17
REV-Mid	21-Aug-14	0	I-0.2	0.74	0.97	10.11
REV-Mid	21-Aug-14	1	I-0.2	1.27	0.85	8.83
REV-Mid	21-Aug-14	2	I-0.2	0.70	0.65	6.82
REV-Mid	21-Aug-14	5	I-0.2	0.99	1.01	10.53
REV-Mid	21-Aug-14	10	I-0.2	0.62	0.69	7.18
REV-Mid	21-Aug-14	13	I-0.2	0.74	0.09	0.95
REV-Mid	21-Aug-14	0	I-2.0	0.58	0.58	6.04
REV-Mid	21-Aug-14	1	I-2.0	0.42	0.56	5.82
REV-Mid	21-Aug-14	2	I-2.0	0.48	0.54	5.61
REV-Mid	21-Aug-14	5	I-2.0	0.53	0.60	6.30
REV-Mid	21-Aug-14	10	I-2.0	0.45	0.40	4.17
REV-Mid	21-Aug-14	13	I-2.0	0.37	0.05	0.49
REV-Mid	21-Aug-14	0	I-20.0	0.08	0.19	2.00
REV-Mid	21-Aug-14	1	I-20.0	0.21	0.22	2.26
REV-Mid	21-Aug-14	2	I-20.0	0.07	0.16	1.66
REV-Mid	21-Aug-14	5	I-20.0	0.07	0.21	2.18
REV-Mid	21-Aug-14	10	I-20.0	0.15	0.15	1.51
REV-Mid	21-Aug-14	13	I-20.0	0.08	0.01	0.12
REV-Mid	25-Sep-14	0	I-0.2	0.98	0.24	10.03
REV-Mid	25-Sep-14	1	I-0.2	0.75	0.41	17.29
REV-Mid	25-Sep-14	2	I-0.2	0.96	0.46	19.43
REV-Mid	25-Sep-14	5	I-0.2	1.03	0.32	13.37
REV-Mid	25-Sep-14	10	I-0.2	1.08	0.08	3.26
REV-Mid	25-Sep-14	15	I-0.2	1.02	0.01	0.26
REV-Mid	25-Sep-14	0	I-2.0	0.49	0.24	10.21
REV-Mid	25-Sep-14	1	I-2.0	0.46	0.30	12.48
REV-Mid	25-Sep-14	2	I-2.0	0.39	0.25	10.58
REV-Mid	25-Sep-14	5	I-2.0	0.42	0.16	6.70
REV-Mid	25-Sep-14	10	I-2.0	0.42	0.01	0.49
REV-Mid	25-Sep-14	15	I-2.0	0.56	0.01	0.23
REV-Mid	25-Sep-14	0	I-20.0	0.55	0.06	2.72
REV-Mid	25-Sep-14	1	I-20.0	0.45	0.08	3.51
REV-Mid	25-Sep-14	2	I-20.0	0.08	0.06	2.65
REV-Mid	25-Sep-14	5	I-20.0	0.07	0.04	1.65
REV-Mid	25-Sep-14	10	I-20.0	0.07	0.03	1.26
REV-Mid	25-Sep-14	15	I-20.0	0.08	0.00	0.17
REV-Mid	25-Sep-14	17	I-20.0	0.09		

Station	Date	Depth (m)	Filter Size (µm)	Chl (mg/m^3)	PP ($mg C/m^3/h$)	PP ($mg C/m^3/day$)
REV-Mid	25-Sep-14	17		0.08		
REV-Mid	25-Sep-14	17		0.07		
REV-Mid	25-Jun-15	0	I-0.2	1.26	0.30	2.12
REV-Mid	25-Jun-15	1	I-0.2	1.28	0.34	2.42
REV-Mid	25-Jun-15	2	I-0.2	1.33	0.41	2.91
REV-Mid	25-Jun-15	5	I-0.2	1.43	0.35	2.52
REV-Mid	25-Jun-15	10	I-0.2	2.82	0.40	2.89
REV-Mid	25-Jun-15	13	I-0.2	2.35	0.21	1.50
REV-Mid	25-Jun-15	0	I-2.0	0.51	0.15	1.09
REV-Mid	25-Jun-15	1	I-2.0	0.60	0.18	1.31
REV-Mid	25-Jun-15	2	I-2.0	0.67	0.28	2.02
REV-Mid	25-Jun-15	5	I-2.0	0.74	0.24	1.74
REV-Mid	25-Jun-15	10	I-2.0	1.18	0.17	1.24
REV-Mid	25-Jun-15	13	I-2.0	1.39	0.08	0.58
REV-Mid	25-Jun-15	0	I-20.0	0.06	0.03	0.20
REV-Mid	25-Jun-15	1	I-20.0	0.07	0.05	0.38
REV-Mid	25-Jun-15	2	I-20.0	0.07	0.06	0.44
REV-Mid	25-Jun-15	5	I-20.0	0.17	0.06	0.42
REV-Mid	25-Jun-15	10	I-20.0	0.13	0.04	0.27
REV-Mid	25-Jun-15	13	I-20.0	0.11	0.01	0.09
REV-Mid	24-Jul-15	0	I-0.2	1.54	0.59	6.56
REV-Mid	24-Jul-15	1	I-0.2	1.49	0.85	9.56
REV-Mid	24-Jul-15	2	I-0.2	1.39	0.94	10.50
REV-Mid	24-Jul-15	5	I-0.2	2.29	0.85	9.51
REV-Mid	24-Jul-15	10	I-0.2	1.33	0.14	1.57
REV-Mid	24-Jul-15	0	I-2.0	0.79	0.35	3.91
REV-Mid	24-Jul-15	1	I-2.0	0.91	0.53	5.96
REV-Mid	24-Jul-15	2	I-2.0	0.88	0.51	5.76
REV-Mid	24-Jul-15	5	I-2.0	1.10	0.48	5.39
REV-Mid	24-Jul-15	10	I-2.0	0.95	0.02	0.21
REV-Mid	24-Jul-15	0	I-20.0	0.19	0.07	0.84
REV-Mid	24-Jul-15	1	I-20.0	0.18	0.19	2.18
REV-Mid	24-Jul-15	2	I-20.0	0.17	0.21	2.39
REV-Mid	24-Jul-15	5	I-20.0	0.21	0.25	2.77
REV-Mid	24-Jul-15	10	I-20.0	0.37	0.01	0.06
REV-Mid	25-Aug-15	0	I-0.2	0.89	0.16	1.65
REV-Mid	25-Aug-15	1	I-0.2	0.57	0.76	7.98
REV-Mid	25-Aug-15	2	I-0.2	1.06	0.61	6.41
REV-Mid	25-Aug-15	5	I-0.2	1.03	0.65	6.84
REV-Mid	25-Aug-15	10	I-0.2	1.35	0.42	4.43
REV-Mid	25-Aug-15	12	I-0.2	0.89	0.03	0.29
REV-Mid	25-Aug-15	0	I-2.0	0.48	0.42	4.47
REV-Mid	25-Aug-15	1	I-2.0	0.46	1.05	11.11
REV-Mid	25-Aug-15	2	I-2.0	0.51	0.33	3.47
REV-Mid	25-Aug-15	5	I-2.0	0.51	0.24	2.48
REV-Mid	25-Aug-15	10	I-2.0	0.50	0.25	2.68
REV-Mid	25-Aug-15	12	I-2.0	0.57	0.04	0.41
REV-Mid	25-Aug-15	0	I-20.0	0.06	0.10	1.03

Station	Date	Depth (m)	Filter Size (µm)	Chl (mg/m^3)	PP (mg C/m^3/h)	PP (mg C/m^3/day)
REV-Mid	25-Aug-15	1	I-20.0	0.06	0.14	1.46
REV-Mid	25-Aug-15	2	I-20.0	0.07	0.16	1.68
REV-Mid	25-Aug-15	5	I-20.0	0.04	0.16	1.70
REV-Mid	25-Aug-15	10	I-20.0	0.13	0.10	1.06
REV-Mid	25-Aug-15	12	I-20.0	0.10	0.01	0.08
REV-Mid	23-Sep-15	0	I-0.2	1.20	0.97	8.65
REV-Mid	23-Sep-15	1	I-0.2	1.32	1.50	13.35
REV-Mid	23-Sep-15	2	I-0.2	1.44	1.04	9.25
REV-Mid	23-Sep-15	5	I-0.2	1.54	1.83	16.32
REV-Mid	23-Sep-15	10	I-0.2	1.35	1.06	9.42
REV-Mid	23-Sep-15	15	I-0.2	0.59	0.08	0.68
REV-Mid	23-Sep-15	0	I-2.0	0.59		
REV-Mid	23-Sep-15	1	I-2.0	0.71		
REV-Mid	23-Sep-15	2	I-2.0	0.65		
REV-Mid	23-Sep-15	5	I-2.0	0.65		
REV-Mid	23-Sep-15	10	I-2.0	0.92		
REV-Mid	23-Sep-15	15	I-2.0	0.20		
REV-Mid	23-Sep-15	0	I-20.0	0.13	0.15	1.34
REV-Mid	23-Sep-15	1	I-20.0	0.12	0.22	1.97
REV-Mid	23-Sep-15	2	I-20.0	0.13	0.22	1.98
REV-Mid	23-Sep-15	5	I-20.0	0.12	0.21	1.86
REV-Mid	23-Sep-15	10	I-20.0	0.11	0.10	0.86
REV-Mid	23-Sep-15	15	I-20.0	0.06	0.03	0.24

Appendix B Integrated Chlorophyll and Primary Productivity

Table B1 Integrated chlorophyll *a* (mg Chl *a*/m^2) for Kinbasket and Revelstoke Reservoir in 2014 & 2015. Stations are: KB = Kinbasket-Forebay, RM = Revelstoke-Middle (also called Downie), RF = Revelstoke-Forebay.

Year	Month	Chlorophyll a (mg Chl *a*/m^2)		
		KB	RM	RF
2014	Jun	36.9	14.7	18.7
2014	Jul	18.3	10.8	15.4
2014	Aug	24.5	10.6	17.9
2014	Sep	35.9	15.3	17.0
2014	**Mean**	**28.9**	**12.8**	**17.3**
2015	Jun	29.7	25.1	12.8
2015	Jul	32.9	17.5	19.8
2015	Aug	28.3	12.8	10.4
2015	Sep	23.6	10.4	15.4
2015	**Mean**	**28.6**	**16.4**	**14.6**

Table B2 Total daily primary productivity (mg C/m^2/d) in Kinbasket and Revelstoke in 2002 and 2008-2015.

Year	Month	Primary Productivity (mg C/m^2/d)		
		KB	**RM**	**RF**
2002	Aug	77.6	-	-
2008	Jul	84.4	33.6	51.8
2008	Aug	42.2	9.6	13.4
2008	Sep	25.3	11.0	18.8
2009	Jun	29.5	11.6	6.9
2009	Jul	11.0	12.1	29.8
2009	Aug	16.5	12.6	11.9
2009	Sep	13.1	10.4	0.5*
2010	Jun	14.8	27.1	32.5
2010	Jul	35.7	24.4	9.9
2010	Aug	43.9	33.8	17.4
2010	Sept	72.9	29.5	33.8
2011	Jun	22.8	24.1	21.6
2011	Jul	41.4	36.3	25.9
2011	Aug	-	25.8	20.5
2011	Sep	-	44.2	44.2
2012	Jun	12.9	5.6	10.6
2012	Jul	38.1	10.7	34.7
2012	Aug	25.0	25.8	21.8
2012	Sep	44.6	19.0	48.9
2013	Jun	87.5	37.5	28.5
2013	Jul	57.8	30.6	40.0
2013	Aug	44.2	28.5	36.7
2013	Sept	77.2	50.6	45.9
2014	Jun	69.87	40.76	26.02
2014	Jul	55.79	40.36	71.99
2014	Aug	49.35	49.08	35.24
2014	Sep	89.99	35.59	63.80
2015	Jun	24.65	15.72	10.29

Year	Month	Primary Productivity (mg C/m^2/d)		
		KB	RM	RF
2015	Jul	90.45	36.68	50.32
2015	Aug	91.51	29.12	65.56
2015	Sep	74.17	68.81	
2008	Mean	50.6	6.0	9.3
2009	Mean	17.5	11.7	16.2
2010	Mean	41.8	28.7	20.0
2011	Mean	32.1	32.6	26.4
2012	Mean	30.2	15.3	29.0
2013	Mean	66.7	36.8	37.8
2014	Mean	66.25	41.45	49.26
2015	Mean	70.20	37.58	42.05

Appendix 6

Phytoplankton
Kinbasket and Revelstoke Reservoirs, 2015

Darren Brandt
Advanced Eco-Solutions

PHYTOPLANKTON POPULATIONS IN KINBASKET AND REVELSTOKE RESERVOIRS, UPPER COLUMBIA BASIN, BRITISH COLUMBIA – 2015

PREPARED FOR:

BC Hydro
1200 Powerhouse Rd.
Revelstoke, BC
V0E 2S0

By

Advanced Eco-Solutions Inc.
25011 E. Trent Ave. Ste. A
P.O. Box 201
Newman Lake, WA 99025

May 2016

This page intentionally left blank.

TABLE OF CONTENTS

TABLE OF TABLES

TABLE OF FIGURES

SECTION 1.0 INTRODUCTION

1.1 Background & Study Purpose

Kinbasket is the first of 3 large reservoirs on the upper reaches of the Columbia River Basin in Canada. It was created upon completion of the Mica Dam over 30 years ago and its discharge flows directly to the upper reaches of Revelstoke Reservoir, the second in the series. Revelstoke Reservoir discharges to the Columbia River and Upper Arrow Lakes Reservoir, the third in the series at the city of Revelstoke, BC. Both Kinbasket and Revelstoke Reservoirs are assumed to be oligotrophic, with low concentrations of total dissolved phosphorus (TDP), low phytoplankton and zooplankton biomass, and low fish production, as is the case in the Arrow Lakes Reservoir which is immediately downstream of Kinbasket and Revelstoke Reservoirs (Pieters et al., 1998). It is hypothesized that one of the factors leading to the low production status of both ecosystems is 'oligotrophication,' or 'nutrient depletion', caused by reservoir aging; i.e. increased water retention increases rates of nutrient utilization within the reservoir as well as increased rates of sedimentation of organic and inorganic particulate carbon (C), i.e. nutrient trapping (Stockner et al. 2000, Pieters et al. 1998, 1999).

This study is part of CLBMON-3 Kinbasket and Revelstoke Reservoirs Ecological Productivity Monitoring under BC Hydro's Columbia River Water Use Plan. Results from 2008 through 2015. in addition to the data from previous studies will permit further commentary on observed changes in phytoplankton density and biomass among depths, stations (sectors) and between years.

SECTION 2.0 METHODS

2.1 Sampling Protocol and Station Locations

Samples were collected from discrete depths at four stations in Kinbasket Reservoir (Canoe, Columbia, Wood, and Forebay)in 2015. Canoe and Wood Arms had samples collected April through September. The Columbia station was sampled from May through September and the Forebay station was sampled from April through October. Samples from three stations in Revelstoke Reservoir (Revelstoke-Forebay, Revelstoke-Mid and Revelstoke-Upper) were taken monthly from April to October in 2015. Phytoplankton communities and density change with depth. Due to this characteristic, discrete samples were taken at depths of 2, 5, 10, 15, and 25 meters. An aliquot of each of these samples was preserved with Lugols for identification and enumeration.

Two depth strata: the epilimnion and hypolimnion were assessed by creating composites of discrete samples. The mean of the densities of taxa from samples collected at 2, 5, and 10 meters were used to determine epilimnetic density and biovolume while samples from 15 and, 25 meters were used to determine the hypolimnetic density and biovolumes. In 2009 and 2008, samples taken at various depths were composited in the field and then identified and enumerated in the laboratory. The change in methodology in 2010 through 2015 is compatible with the previous sampling methodology; however, the taxa richness could be higher in the composited samples from 2010 through 2015 since counting multiple samples and then compositing them after identification and enumeration will result in an increase in the fraction of the sample counted than counting a single field composited sample.

At each station an aliquot of composited water from the epilimnion (0-10 meters) and hypolimnion (15-25 meters) was taken for bacterial and pico-cyanobacterial enumeration. Bacteria samples were preserved with three drops of 25% glutaraldehyde and placed in a small, brown polyethylene bottle.

2.2 Enumeration Protocol

2.2.1 Phytoplankton

Phytoplankton samples were preserved in the field in acid Lugol's iodine preservative and shipped to Advanced Eco-Solutions Inc. in Newman Lake, WA for enumeration. The samples were gently shaken for 60 seconds and poured into 25 mL settling chambers and allowed to settle for a minimum of 3 hrs prior to quantitative enumeration using the Utermohl Method (Utermohl 1958). Counts were done using a plankton microscope. All cells within a random transect of 3.5 mm in length were counted at high power (900X magnification) that permitted a semi-quantitative enumeration of minute (<2 μ) autotrophic pico-cyanobacteria cells (1.0-2.0 μ) [Class Cyanophyceae], and of small, delicate auto-, mixo- and heterotrophic nano-flagellates (2.0-20.0 μ) [Classes Chrysophyceae and Cryptophyceae]. Comments on the relative density of ciliates in each sample were also noted on count sheets. Where feasible, from 250-300 cells were enumerated in each sample to assure counting consistency and statistical accuracy (Lund et al. 1958). The compendium of Canter-Lund and Lund (1995) was used as a taxonomic reference. The primary taxonomist was Nichole Manley of Advanced Eco-Solutions Inc.

2.2.2 Bacteria and Pico-cyanobacteria

Fifteen milliliters of sample water was filtered for pico-cyano bacteria density determination. A second aliquot of 5 mL was inoculated with a fluorescent dye (DAPI) for autotrophic picoplankton (heterotrophic bacteria) determination. Both of these sub-samples were filtered through black 0.2 polycarbonate Nucleopore filters. The bacteria become trapped on the surface of the filters. The number of cells in a given filter area was then used to determine bacteria densities. Pico-cyano bacteria densities were determined using direct count epiflourescence method described by MacIsaac et al. (1993 and heterotrophic bacteria was enumerated using the epiflourescence method described by MacIsaac and Stockner (1993). Eight to 32 random fields on each of the filters were counted at 1000x magnification using either blue-band excitation filter (450-490nm) for pico-cyano bacteria or a UV wide-band excitation filter (397-560nm) for heterotrophic bacteria density determination. Heterotrophic bacteria and pico-cyanobacterial densities are reported as cells/mL. Pico-plankton enumeration is an emerging plankton technique and is not yet commonly used in other lake systems. To facilitate comparison of phytoplankton densities in Revelstoke and Kinbasket to other systems and to previous data from the reservoirs the densities of picoplankton were not added to the total phytoplankton counts. The total density of autotrophs can be calculated by summing the phytoplankton and picoplankton if so desired.

SECTION 3.0 RESULTS

3.1 Study Limitations

As a caveat, it should be noted that the number of stations sampled (four in Kinbasket and three in Revelstoke), and sampling frequency (monthly) provide only an approximation of phytoplankton population density, biomass, diversity, and spatiotemporal variability in two of the largest Upper Columbia Basin's reservoirs. Interpretations in this report are made on observed patterns of only two variables, *Density* (cells/mL) of groups and their respective taxonomic Classes, and *Biovolume* (mm^3/L) or biomass of groups and Classes. Thus, this report should essentially be considered more as an 'overview' of the current status of phytoplankton populations in Kinbasket and Revelstoke rather than a comprehensive 'synthesis' of phytoplankton community dynamics.

3.2 Phytoplankton Density and Biovolume by Class – 2015

A complete list of the taxa identified in Kinbasket and Revelstoke Reservoirs in 2015 can be found in Appendix A. The taxa are organized into major taxonomic groups that are used throughout the report.

3.2.1 Epilimnion

Kinbasket

In Kinbasket Reservoir blue-greens (cyanophytes)were the most abundant group in the epilimnion, followed by flagellates (chryso/cryptophytes), with greens (chlorophytes), diatoms (bacillariophytes), and dinoflagellates (dinophytes) considerably less abundant (Table 1 and Figure 1). In terms of density, the major taxa contributing to the high density of the flagellates were microflagellates. The cyanophytes were dominated by Synechococcus (coccoids). Peak phytoplankton density occurred at the Canoe Station in June (14,968 cells/mL) (Figure 3).The Wood Station had the lowest phytoplankton density at 4,277 cells/mL in August. On a seasonal average the four stations had similar mean phytoplankton densities.

In terms of biovolume, the major contributors throughout the season were greens, flagellates and blue-greens, followed by diatoms, and dinoflagellates (Figure 2). The Columbia station had the highest seasonal mean biomass of the stations (Table 2 and Figure 4).

Table 1 Kinbasket Reservoir mean phytoplankton density (Cells/mL) by group and month from the 2, 5 and 10 meter laboratory composites in 2015

Station	Group	April	May	June	July	August	Sept.	Oct.	Seasonal Average
Kin-Canoe	Blue-greens	3,821	5,390	7,220	3,797	4,106	2,049		4,397
	Coccoid Greens, Desmids, etc.	325	667	992	740	1,049	472		707
	Diatoms	41	89	171	829	683	480		382
	Dinoflagellates	24	81	179	179	73	33		95
	Flagellates	2,838	3,683	6,407	3,407	3,911	1,626		3,645
	Sum of All Groups	7,049	9,911	14,968	8,952	9,822	4,659		9,227
Kin-Columbia	Blue-greens		2,919	3,081	4,854	3,122	4,813		3,758
	Coccoid Greens, Desmids, etc.		846	642	1,049	886	862		857
	Diatoms		73	171	1,382	984	520		626
	Dinoflagellates		171	163	187	89	106		143
	Flagellates		2,959	3,212	4,667	2,789	4,244		3,574
	Sum of All Groups		6,968	7,269	12,139	7,870	10,545		8,958
Kin-Forebay	Blue-greens	3,260	2,480	3,285	4,033	1,610	3,342	2,903	2,987
	Coccoid Greens, Desmids, etc.	407	789	854	862	634	707	610	695
	Diatoms	24	24	195	756	1,260	699	236	456
	Dinoflagellates	16	122	163	244	98	106	81	118
	Flagellates	2,577	2,781	3,675	3,358	1,512	2,455	2,683	2,720
	Sum of All Groups	6,285	6,195	8,171	9,252	5,114	7,309	6,512	6,977
Kin-Wood	Blue-greens	1,837	2,464	6,057	4,334	1,220	2,602		3,086
	Coccoid Greens, Desmids, etc.	366	968	1,016	650	504	504		668
	Diatoms	24	49	138	1,122	1,260	610		534
	Dinoflagellates	16	211	203	138	73	98		123
	Flagellates	2,504	4,187	5,586	3,789	1,220	2,423		3,285
	Sum of All Groups	4,748	7,878	13,001	10,033	4,277	6,236		7,695

Table 2 Kinbasket Reservoir mean phytoplankton biovolume (mm^3/L) by group and month from the 2, 5 and 10 meter laboratory composites in 2015

Station	Group	April	May	June	July	August	Sept.	Oct.	Seasonal Average
Kin-Canoe	Blue-greens	0.0150	0.0391	0.0315	0.0229	0.0204	0.0098		0.0231
	Coccoid Greens, Desmids, etc.	0.0172	0.0587	0.1126	0.2067	0.2174	0.1286		0.1235
	Diatoms	0.0047	0.0121	0.0508	0.0718	0.0659	0.0244		0.0383
	Dinoflagellates	0.0049	0.0089	0.0256	0.0329	0.0118	0.0085		0.0154
	Flagellates	0.0342	0.0630	0.1139	0.0706	0.0733	0.0361		0.0652
	Sum of All Groups	0.0759	0.1819	0.3344	0.4050	0.3887	0.2074		0.2656
Kin-Columbia	Blue-greens		0.0237	0.0145	0.0233	0.0166	0.0214		0.0199
	Coccoid Greens, Desmids, etc.		0.1650	0.1202	0.2718	0.1189	0.3073		0.1966
	Diatoms		0.0087	0.0278	0.1220	0.0606	0.0447		0.0528
	Dinoflagellates		0.0276	0.0285	0.0309	0.0085	0.0175		0.0226
	Flagellates		0.0755	0.0795	0.0862	0.0726	0.0755		0.0779
	Sum of All Groups		0.3006	0.2704	0.5341	0.2772	0.4664		0.3697
Kin-Forebay	Blue-greens	0.0148	0.0165	0.0172	0.0201	0.0084	0.0214	0.0156	0.0163
	Coccoid Greens, Desmids, etc.	0.1044	0.1319	0.2073	0.1706	0.1288	0.0986	0.0852	0.1324
	Diatoms	0.0028	0.0022	0.0374	0.0799	0.0748	0.0407	0.0175	0.0365
	Dinoflagellates	0.0033	0.0260	0.0321	0.0455	0.0244	0.0220	0.0110	0.0235
	Flagellates	0.0281	0.0768	0.0802	0.0769	0.0411	0.0572	0.0500	0.0586
	Sum of All Groups	0.1534	0.2536	0.3742	0.3931	0.2775	0.2398	0.1792	0.2673
Kin-Wood	Blue-greens	0.0073	0.0166	0.0256	0.0255	0.0050	0.0107		0.0151
	Coccoid Greens, Desmids, etc.	0.0416	0.1575	0.2386	0.1192	0.0989	0.0946		0.1251
	Diatoms	0.0022	0.0073	0.0165	0.0872	0.0870	0.0435		0.0406
	Dinoflagellates	0.0033	0.0366	0.0313	0.0260	0.0179	0.0154		0.0217
	Flagellates	0.0259	0.0874	0.0913	0.0635	0.0306	0.0523		0.0585
	Sum of All Groups	0.0803	0.3054	0.4032	0.3213	0.2394	0.2165		0.2610

Figure 1 Average phytoplankton density (Cells/mL) in Kinbasket Reservoir in 2015 derived from the 2, 5, 10 meter laboratory composites

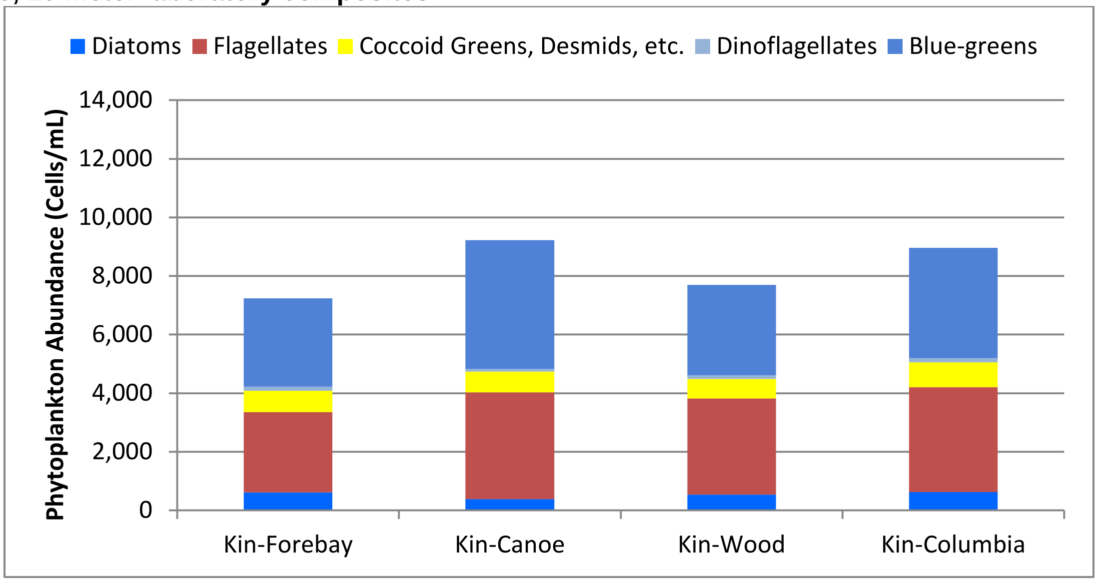


Figure 2 Average phytoplankton biovolume (mm^3/L) in Kinbasket Reservoir in 2015 derived from the 2, 5, and 10 meter laboratory composites

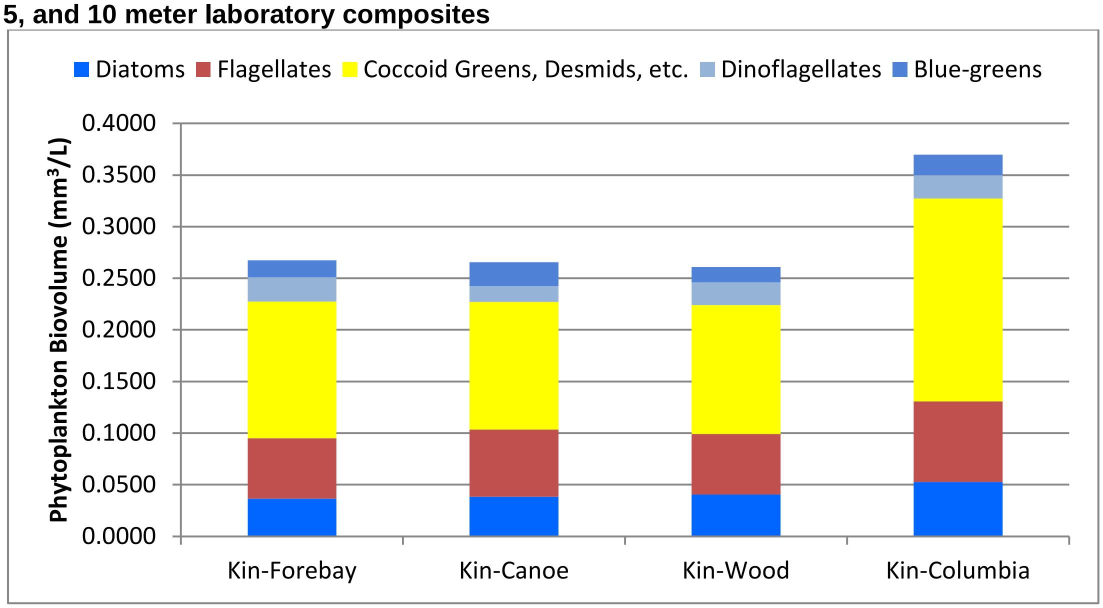


Figure 3 Kinbasket mean epilimnetic phytoplankton density by month for 2015

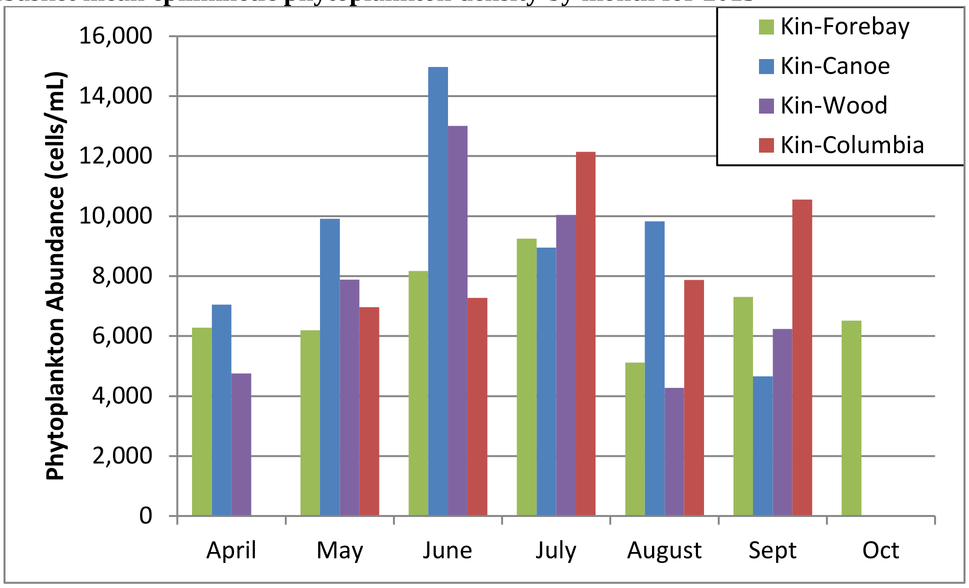
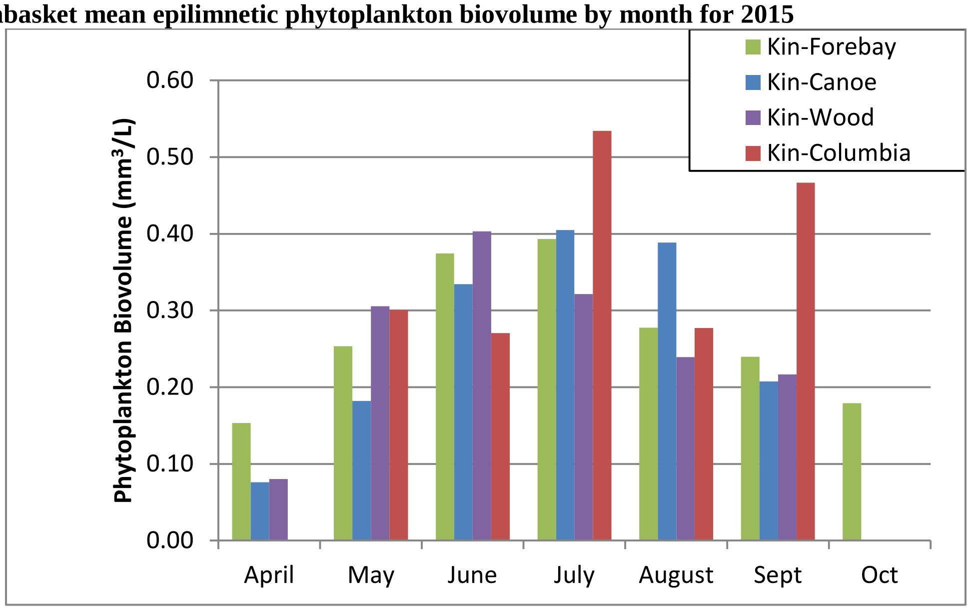


Figure 4 Kinbasket mean epilimnetic phytoplankton biovolume by month for 2015



Revelstoke

The dominant taxonomic groups in Revelstoke are the blue-greens and flagellates (Table 3 and Figure 5). The mean overall cell density is slightly higher than those observed in Kinbasket (8,214 cells/mL) compared to Revelstokes 9,132 cells/mL. Based on biovolume, the taxonomic group making up the largest percentage of the phytoplankton community are the flagellates and blue-greens followed by greens, diatoms and dinoflagellates (Table 4 and Figure 6).

Peak epilimnetic phytoplankton density occurred at the Mid station in July and in terms of biovolume the the peak occurred in June at the Mid station (17,464 cells/mL and 0.3068 mm^3/L) (Figure 7 and Figure 8). The Middle station also had the lowest phytoplankton density (3,976 cells/mL), and biovolume (0.09 mm^3/L) in April.

Table 3 Revelstoke Reservoir mean phytoplankton density (Cells/mL) by group and month from the 2, 5 and 10 meter laboratory composites 2015

Station	Group	April	May	June	July	August	Sept.	Oct.	Seasonal Average
Rev-Forebay	Blue-greens	2,732	2,707	2,114	9,935	2,008	3,683	8,033	4,459
	Coccoid Greens, Desmids, etc.	537	951	691	553	577	789	756	693
	Diatoms	81	81	114	358	98	138	41	130
	Dinoflagellates	33	163	98	89	73	130	114	100
	Flagellates	2,309	2,260	2,179	3,577	1,789	2,992	6,106	3,030
	Sum of All Groups	5,691	6,163	5,195	14,513	4,545	7,732	15,049	8,413
Rev-Mid	Blue-greens	1,716	3,260	6,472	10,862	4,049	4,683	6,602	5,378
	Coccoid Greens, Desmids, etc.	325	602	1,098	699	585	699	772	683
	Diatoms	73	73	122	488	49	154	8	138
	Dinoflagellates	41	187	187	122	122	65	220	135
	Flagellates	1,821	3,439	6,293	5,293	3,594	3,992	7,943	4,625
	Sum of All Groups	3,976	7,561	14,171	17,464	8,399	9,594	15,545	10,959
Rev-Upper	Blue-greens	2,211	3,195	4,179	4,854	3,268	4,057	4,228	3,713
	Coccoid Greens, Desmids, etc.	358	691	886	667	642	569	732	649
	Diatoms	81	81	138	163	114	57	73	101
	Dinoflagellates	33	195	195	122	98	81	122	121
	Flagellates	2,098	3,057	4,147	4,114	3,025	3,683	3,951	3,439
	Sum of All Groups	4,781	7,220	9,545	9,919	7,147	8,448	9,106	8,024

Table 4 Revelstoke Reservoir mean phytoplankton biovolume (mm^3/L) by group and month from the 2, 5 and 10 meter laboratory composites in 2015

Station	Group	April	May	June	July	August	Sept.	Oct.	Seasonal Average
Rev-Forebay	Blue-greens	0.0131	0.0147	0.0084	0.0459	0.0101	0.0207	0.0421	0.0221
	Coccoid Greens, Desmids, etc.	0.0390	0.0998	0.0710	0.0901	0.1144	0.1649	0.1848	0.1092
	Diatoms	0.0129	0.0192	0.0111	0.0437	0.0057	0.0157	0.0061	0.0163
	Dinoflagellates	0.0098	0.0248	0.0159	0.0159	0.0191	0.0183	0.0252	0.0184
	Flagellates	0.0319	0.0499	0.0486	0.0402	0.0428	0.0763	0.0749	0.0521
	Sum of All Groups	0.1067	0.2084	0.1550	0.2358	0.1922	0.2959	0.3331	0.2182
Rev-Mid	Blue-greens	0.0109	0.0173	0.0356	0.0474	0.0182	0.0274	0.0326	0.0271
	Coccoid Greens, Desmids, etc.	0.0221	0.0733	0.1952	0.1024	0.1058	0.1632	0.1792	0.1202
	Diatoms	0.0095	0.0103	0.0187	0.0901	0.0102	0.0240	0.0008	0.0234
	Dinoflagellates	0.0098	0.0256	0.0309	0.0203	0.0183	0.0171	0.0301	0.0217
	Flagellates	0.0381	0.0656	0.0929	0.0789	0.0515	0.0583	0.1123	0.0711
	Sum of All Groups	0.0903	0.1921	0.3734	0.3391	0.2040	0.2900	0.3550	0.2634
Rev-Upper	Blue-greens	0.0167	0.0165	0.0265	0.0194	0.0131	0.0182	0.0210	0.0188
	Coccoid Greens, Desmids, etc.	0.0497	0.1165	0.1726	0.1822	0.1189	0.1249	0.1604	0.1322
	Diatoms	0.0181	0.0118	0.0211	0.0171	0.0063	0.0110	0.0077	0.0133
	Dinoflagellates	0.0114	0.0346	0.0309	0.0211	0.0232	0.0134	0.0114	0.0208
	Flagellates	0.0334	0.0731	0.0768	0.0618	0.0531	0.0535	0.0671	0.0598
	Sum of All Groups	0.1294	0.2525	0.3279	0.3017	0.2147	0.2210	0.2677	0.2450

Figure 5 Average phytoplankton density (Cells/mL) in Revelstoke Reservoir between April - September 2015 derived from the 2, 5, and 10 meter laboratory composites

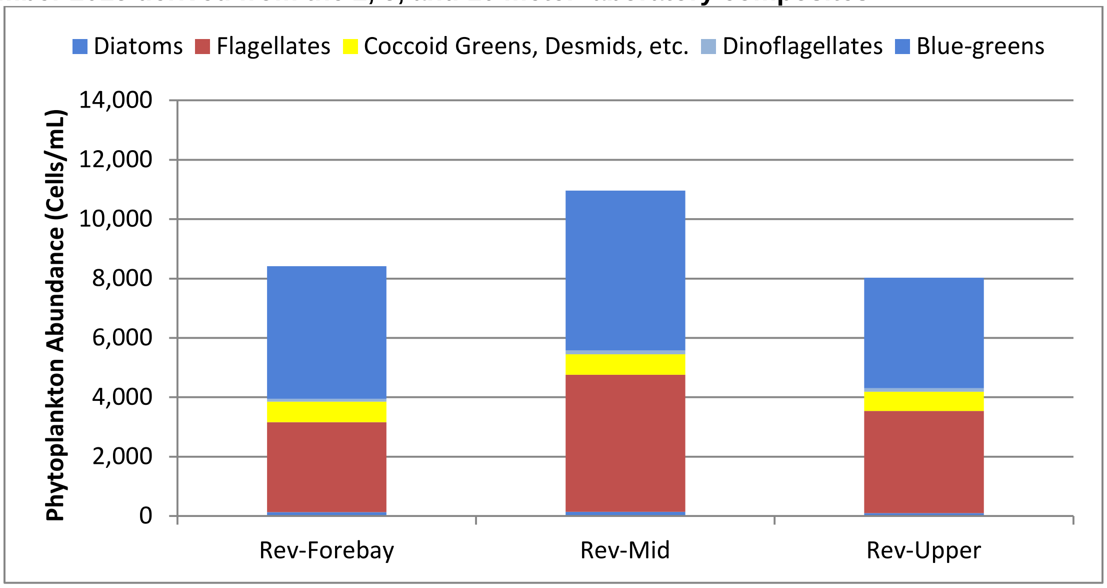


Figure 6 Average phytoplankton biovolume (mm^3/L) in Revelstoke Reservoir between May - October 2015 derived from the 2, 5, and 10 meter laboratory composites

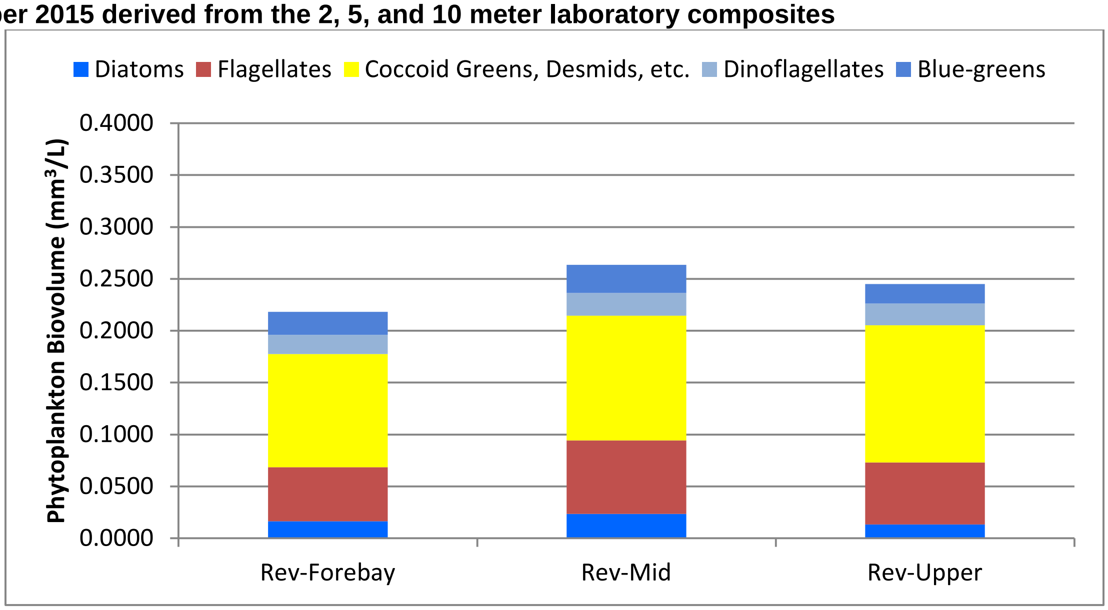


Figure 7 Revelstoke mean epilimnetic phytoplankton density by month

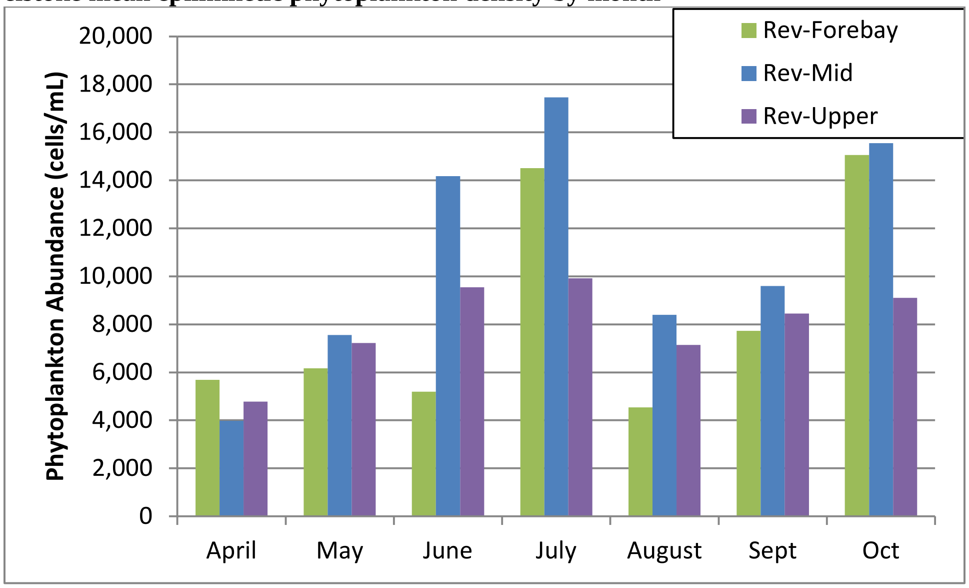
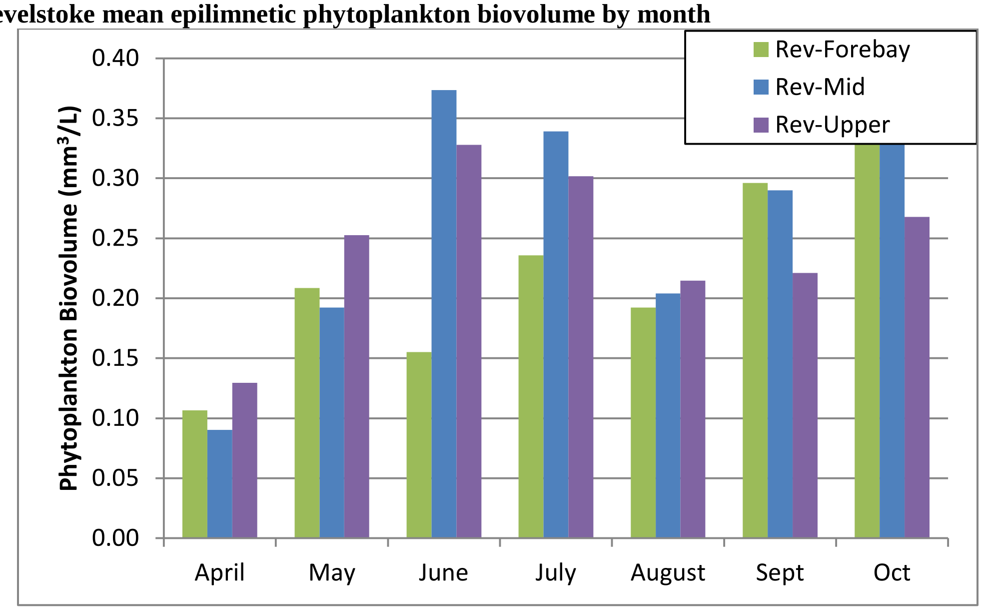


Figure 8 Revelstoke mean epilimnetic phytoplankton biovolume by month



3.2.2 Hypolimnion

Kinbasket

Hypolimnetic phytoplankton densities in Kinbasket Reservoir were lower than epilimnetic densities. Blue-Greens were the most abundant group, followed by flagellates. Diatoms, greens and dinoflagellates were minor contributors to hypolimnetic phytoplankton density (Table 5 and Figure 9). In terms of biovolume, greens, blue-greens and flagellates were the largest contributors followed by diatoms and dinoflagellates (Table 6 and Figure 10). The Wood station had the highest seasonal average phytoplankton density

(12,265 cells/mL) and the Columbia station had the highest seasonal average of biovolume (0.3300 mm^3/L). The month of July had the highest hypolimnetic phytoplankton cell densities (Figure 11).

Table 5 Kinbasket Reservoir hypolimnion phytoplankton density (Cells/mL) by group and month from the 15, and 25 meter laboratory composites in 2015

Station	Group	April	May	June	July	August	Sept.	Oct.	Seasonal Average
Kin-Canoe	Blue-greens	3,659	4,549	4,220	4,878	3,573	2,342		3,870
	Coccoid Greens, Desmids, etc.	354	500	1,890	695	1,439	622		917
	Diatoms	49	98	122	122	402	634		238
	Dinoflagellates	12	73	146	244	134	49		110
	Flagellates	2,988	3,110	2,951	4,268	3,305	2,085		3,118
	Sum of All Groups	7,061	8,330	9,330	10,208	8,854	5,732		8,252
Kin-Columbia	Blue-greens		2,073	4,427	9,744	3,268	4,903		4,883
	Coccoid Greens, Desmids, etc.		610	695	1,866	1,049	683		981
	Diatoms		61	73	110	744	268		251
	Dinoflagellates		98	134	268	146	24		134
	Flagellates		2,415	4,366	8,769	3,232	4,244		4,605
	Sum of All Groups		5,256	9,696	20,757	8,439	10,122		10,854
Kin-Forebay	Blue-greens	1,878	2,476	2,732	3,037	1,842	2,683	3,525	2,596
	Coccoid Greens, Desmids, etc.	232	744	671	988	695	683	549	652
	Diatoms	49	0	122	268	488	476	256	237
	Dinoflagellates	24	122	171	110	110	37	49	89
	Flagellates	1,842	3,512	3,012	2,854	1,915	2,622	2,781	2,648
	Sum of All Groups	4,025	6,854	6,708	7,256	5,049	6,500	7,159	6,222
Kin-Wood	Blue-greens	2,500	1,671	7,354	14,037	3,549	5,500		5,769
	Coccoid Greens, Desmids, etc.	390	744	915	1,085	768	781		781
	Diatoms	12	24	110	439	744	232		260
	Dinoflagellates	12	110	195	159	37	146		110
	Flagellates	2,500	3,317	7,452	11,074	2,976	4,756		5,346
	Sum of All Groups	5,415	5,866	16,025	26,794	8,074	11,415		12,265

Table 6 Kinbasket Reservoir phytoplankton biovolume (mm^3/L) by group and month from the 15, and 25 meter laboratory composites in 2015

Station	Group	April	May	June	July	August	Sept.	Oct.	Seasonal Average
Kin-Canoe	Blue-greens	0.0174	0.0224	0.0174	0.0257	0.0232	0.0124		0.0197
	Coccoid Greens, Desmids, etc.	0.0583	0.0377	0.2115	0.2409	0.2489	0.1502		0.1579
	Diatoms	0.0055	0.0107	0.0235	0.0146	0.0329	0.0329		0.0200
	Dinoflagellates	0.0049	0.0159	0.0232	0.0470	0.0171	0.0085		0.0194
	Flagellates	0.0306	0.0496	0.0779	0.0781	0.0594	0.0527		0.0581
	Sum of All Groups	0.1167	0.1363	0.3535	0.4062	0.3815	0.2568		0.2752
Kin-Columbia	Blue-greens		0.0114	0.0251	0.0454	0.0162	0.0196		0.0235
	Coccoid Greens, Desmids, etc.		0.0401	0.1685	0.4446	0.1238	0.1793		0.1913
	Diatoms		0.0122	0.0082	0.0098	0.0390	0.0146		0.0168
	Dinoflagellates		0.0146	0.0165	0.0567	0.0134	0.0098		0.0222
	Flagellates		0.0541	0.0654	0.1138	0.0796	0.0685		0.0763
	Sum of All Groups		0.1324	0.2835	0.6703	0.2720	0.2919		0.3300
Kin-Forebay	Blue-greens	0.0077	0.0133	0.0197	0.0299	0.0193	0.0229	0.0173	0.0186
	Coccoid Greens, Desmids, etc.	0.0450	0.1507	0.1426	0.1191	0.1187	0.1880	0.1706	0.1335
	Diatoms	0.0041	0.0000	0.0235	0.0396	0.0476	0.0409	0.0146	0.0243
	Dinoflagellates	0.0073	0.0146	0.0341	0.0250	0.0201	0.0018	0.0067	0.0157
	Flagellates	0.0286	0.1063	0.0528	0.0495	0.0567	0.0702	0.0515	0.0594
	Sum of All Groups	0.0927	0.2850	0.2728	0.2631	0.2624	0.3238	0.2607	0.2515
Kin-Wood	Blue-greens	0.0130	0.0072	0.0324	0.0594	0.0200	0.0281		0.0267
	Coccoid Greens, Desmids, etc.	0.0262	0.1211	0.1096	0.2528	0.1037	0.1349		0.1247
	Diatoms	0.0012	0.0030	0.0205	0.0384	0.0494	0.0128		0.0209
	Dinoflagellates	0.0098	0.0201	0.0299	0.0470	0.0018	0.0232		0.0220
	Flagellates	0.0217	0.0968	0.0784	0.0927	0.0546	0.0776		0.0703
	Sum of All Groups	0.0719	0.2482	0.2707	0.4903	0.2295	0.2765		0.2645

Figure 9 Average phytoplankton density (Cells/mL) in Kinbasket Reservoir between April - August 2015 derived from the 15, and 25 meter laboratory composites

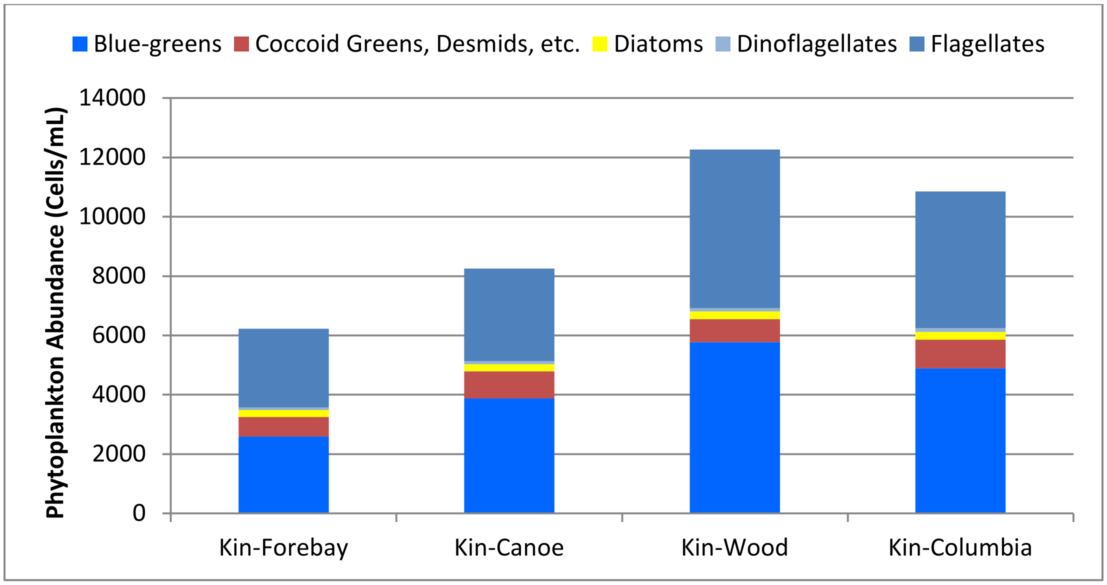


Figure 10 Average phytoplankton biovolume (mm^3/L) in Kinbasket Reservoir between April - August 2015 derived from the 15, and 25 meter laboratory composites

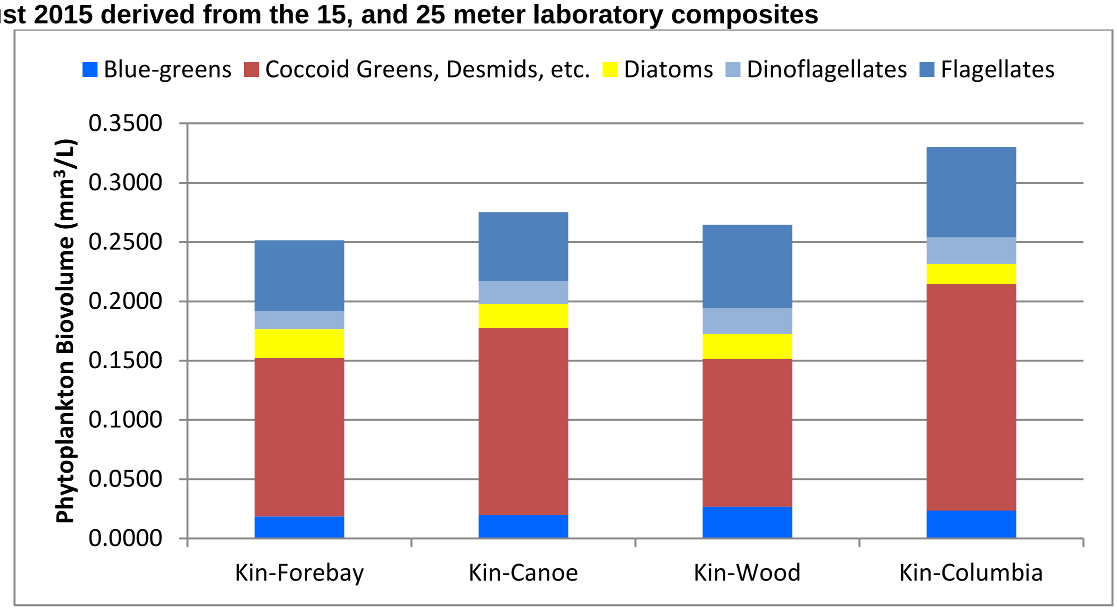


Figure 11 Kinbasket mean hypolimnetic phytoplankton density by month

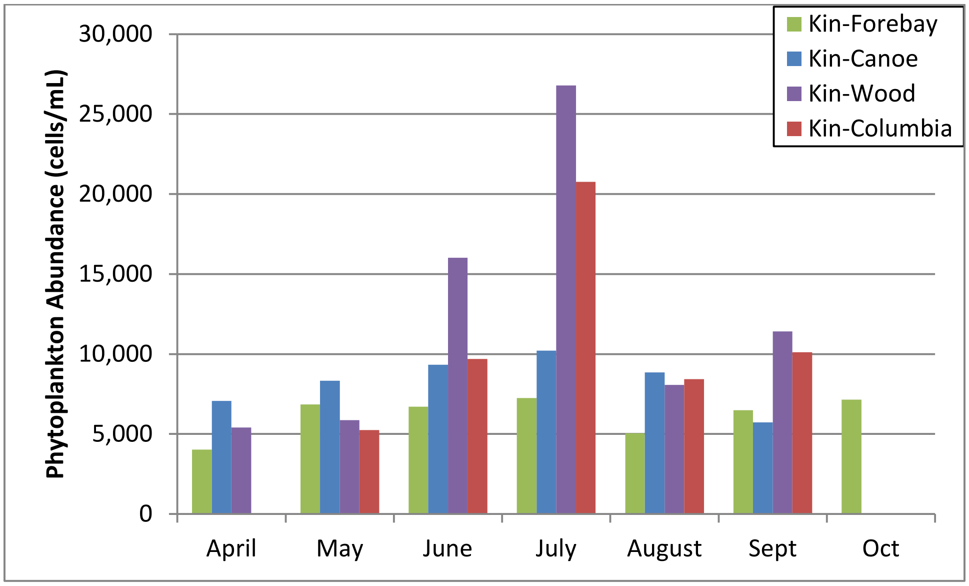
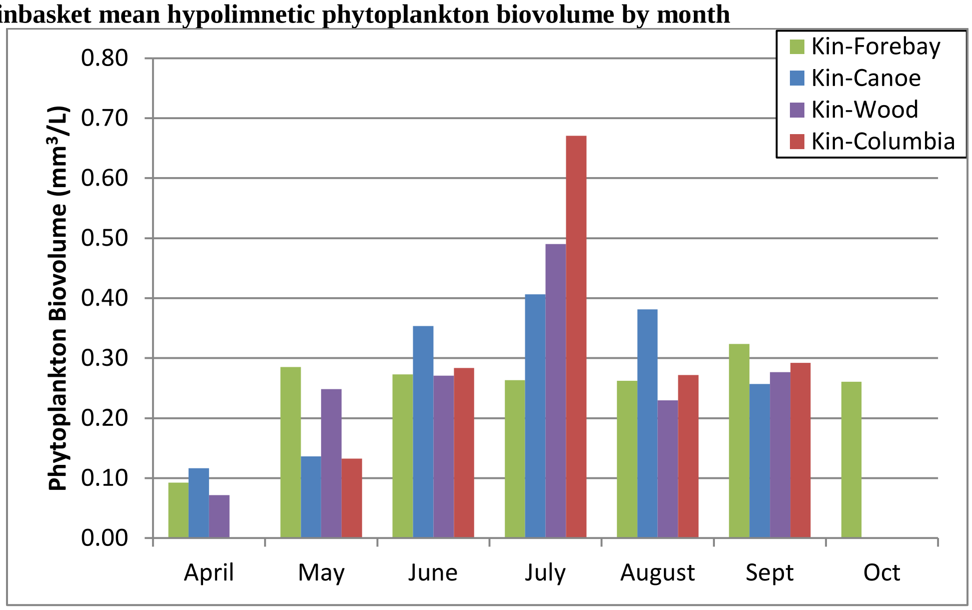


Figure 12 Kinbasket mean hypolimnetic phytoplankton biovolume by month



Revelstoke

The most abundant groups in the hypolimnion of Revelstoke Reservoir in 2015 were blue-greens and flagellates. The least abundant groups present were dinoflagellates and diatoms (Table 7 and Figure 13). The greatest contributors to biovolume at all stations were flagellates and the greens. Diatoms and dinoflagellates contributed the least to biovolume (Table 8 and Figure 14). The Middle station had the highest mean cell density and biovolumes of the three Revelstoke stations, followed by the Upper and Forebay stations.

July had the highest phytoplankton density in the hypolimnion (Figure 15 and Figure 16). This is primarily the result of an unusually dense phytoplankton sample at 15 meters of depth in the Middle Station in July.

Table 7 Revelstoke Reservoir phytoplankton density (Cells/mL) by group and month from the 15, and 25 meter laboratory composites in 2015

Station	Group	April	May	June	July	August	Sept.	Oct.	Seasonal Average
Rev-Forebay	Blue-greens	3,037	1,854	3,378	4,573	4,561	3,415	9,744	4,366
	Coccoid Greens, Desmids, etc.	671	659	720	768	720	683	768	713
	Diatoms	24	85	49	85	24	24	49	49
	Dinoflagellates	73	98	171	61	49	146	195	113
	Flagellates	2,561	2,085	3,415	3,281	2,915	2,903	6,756	3,417
	Sum of All Groups	6,366	4,781	7,732	8,769	8,269	7,171	17,513	8,657
Rev-Mid	Blue-greens	1,768	2,951	6,330	6,720	2,573	4,037	5,549	4,275
	Coccoid Greens, Desmids, etc.	1,890	707	1,037	805	500	537	390	838
	Diatoms	73	49	61	73	73	37	24	56
	Dinoflagellates	37	146	98	85	61	73	110	87
	Flagellates	902	2,573	6,098	5,951	2,378	3,488	4,488	3,697
	Sum of All Groups	4,671	6,427	13,623	13,635	5,586	8,171	10,561	8,953
Rev-Upper	Blue-greens	1,903	4,122	4,012	4,878	2,829	2,744	5,854	3,763
	Coccoid Greens, Desmids, etc.	390	768	671	1,183	439	439	1,000	699
	Diatoms	61	134	85	98	73	110	73	91
	Dinoflagellates	49	134	110	183	61	159	85	112
	Flagellates	2,024	3,281	3,744	4,415	2,537	3,000	4,683	3,383
	Sum of All Groups	4,427	8,439	8,622	10,757	5,939	6,452	11,696	8,047

Table 8 Revelstoke Reservoir phytoplankton biovolume (mm^3/L) by group and month from the 15, and 25 meter laboratory composites in 2015

Station	Group	May	June	July	August	Sept.	Oct.	Seasonal Average
Rev-Forebay	Blue-greens	0.0241	0.0076	0.0167	0.0183	0.0214	0.0226	0.0392
	Coccoid Greens, Desmids, etc.	0.0419	0.0836	0.1167	0.1040	0.2090	0.1457	0.1435
	Diatoms	0.0024	0.0122	0.0159	0.0213	0.0037	0.0012	0.0046
	Dinoflagellates	0.0293	0.0220	0.0287	0.0049	0.0128	0.0305	0.0159
	Flagellates	0.0324	0.0425	0.0527	0.0443	0.0423	0.0629	0.0898
	Sum of All Groups	0.1301	0.1678	0.2307	0.1929	0.2891	0.2628	0.2930
Rev-Mid	Blue-greens	0.0071	0.0180	0.0286	0.0329	0.0132	0.0161	0.0222
	Coccoid Greens, Desmids, etc.	0.1031	0.0824	0.2879	0.3144	0.1165	0.1660	0.0549
	Diatoms	0.0193	0.0043	0.0050	0.0174	0.0162	0.0024	0.0055
	Dinoflagellates	0.0122	0.0256	0.0177	0.0061	0.0030	0.0232	0.0073
	Flagellates	0.0235	0.0587	0.0785	0.0745	0.0364	0.0404	0.0502
	Sum of All Groups	0.1652	0.1891	0.4177	0.4454	0.1853	0.2481	0.1401
Rev-Upper	Blue-greens	0.0107	0.0232	0.0218	0.0348	0.0173	0.0111	0.0235
	Coccoid Greens, Desmids, etc.	0.0655	0.0870	0.2355	0.2441	0.1562	0.0692	0.1284
	Diatoms	0.0054	0.0170	0.0080	0.0083	0.0040	0.0063	0.0067
	Dinoflagellates	0.0079	0.0317	0.0189	0.0256	0.0183	0.0427	0.0079
	Flagellates	0.0268	0.0756	0.0568	0.0899	0.0382	0.0521	0.0634
	Sum of All Groups	0.1163	0.2345	0.3411	0.4027	0.2340	0.1815	0.2299

Figure 13 Average phytoplankton density (Cells/mL) in Revelstoke Reservoir between May - October 2015 derived from the 15, and 25 meter laboratory composites

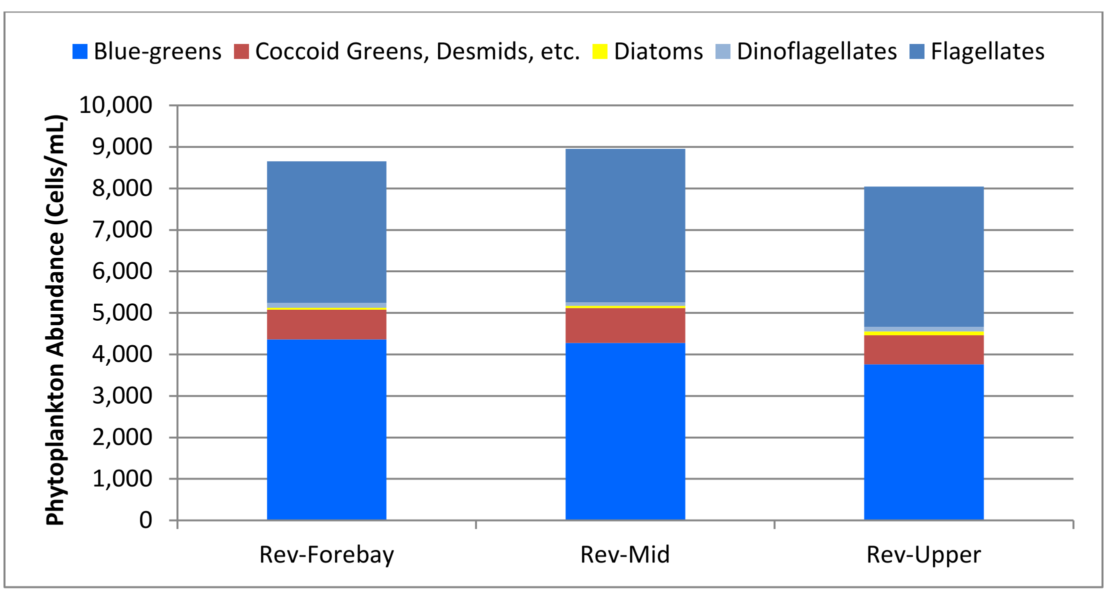


Figure 14 Average phytoplankton biovolume (mm^3/L) in Revelstoke Reservoir between May - October 2015 derived from the 15, and 25 meter laboratory composites

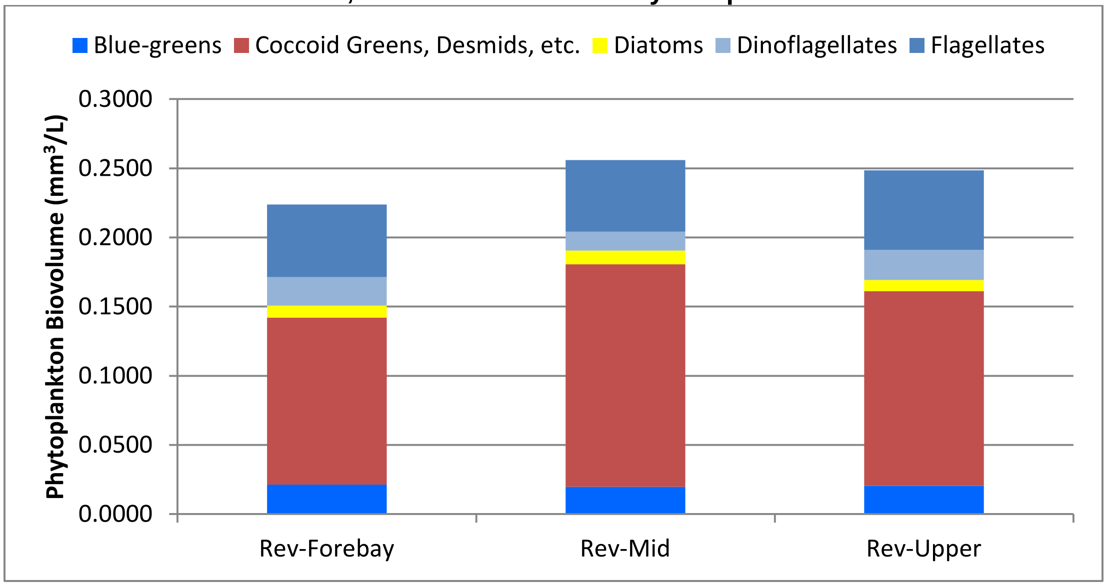


Figure 15 Revelstoke mean hypolimnetic phytoplankton density by month

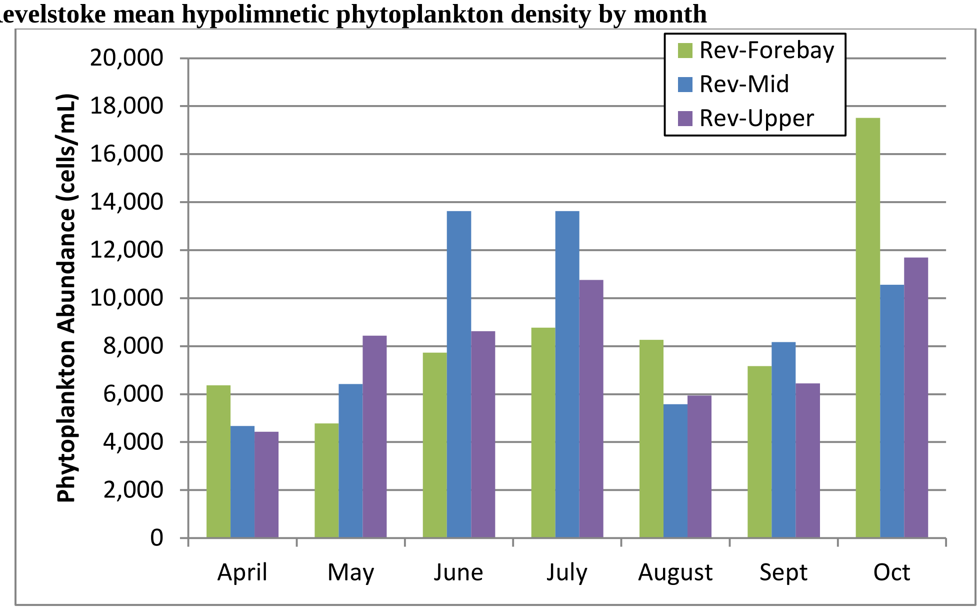
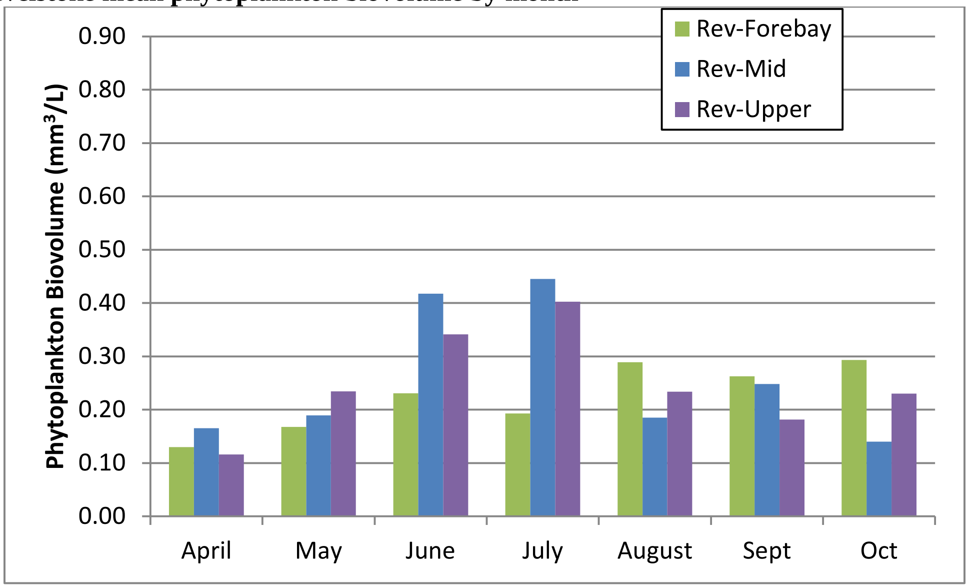


Figure 16 Revelstoke mean phytoplankton biovolume by month



3.3 Vertical Distribution- Phytoplankton Density and Biovolume – 2015

Average density (cells/mL) and average biovolume (mm^3/L) of phytoplankton groups were calculated for individual depth strata for both Kinbasket and Revelstoke Reservoirs. The averages were based on every sample collected at each station within the respective reservoirs during the 2015 sampling season.

Kinbasket

Blue-Greens and flagellates dominated the community at all depths (Figure 17). The average density was the highest at 25 meters. The 2015 biovolume of the phytoplankton community does exhibits little difference with depth (Figure 18).

Figure 17 Average phytoplankton density (Cells/mL), by depth and group, in Kinbasket Reservoir in 2015

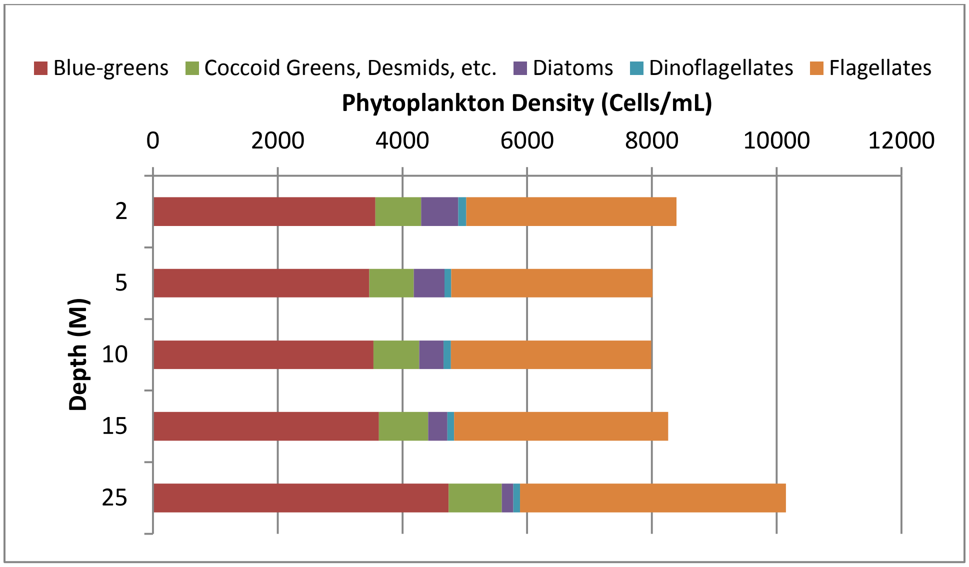
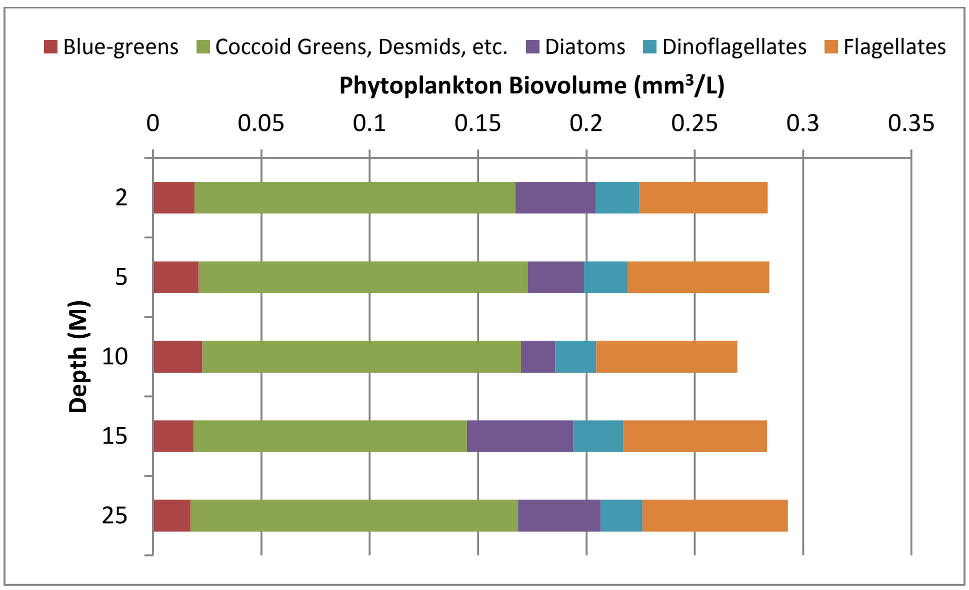


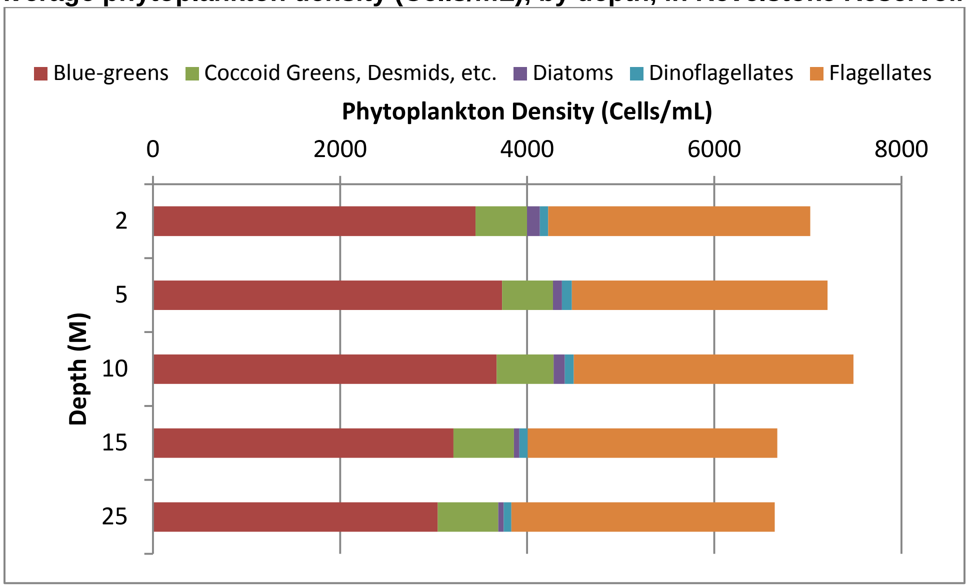
Figure 18 Average phytoplankton biovolume (mm^3/L), by depth and group, in Kinbasket Reservoir in 2015



Revelstoke

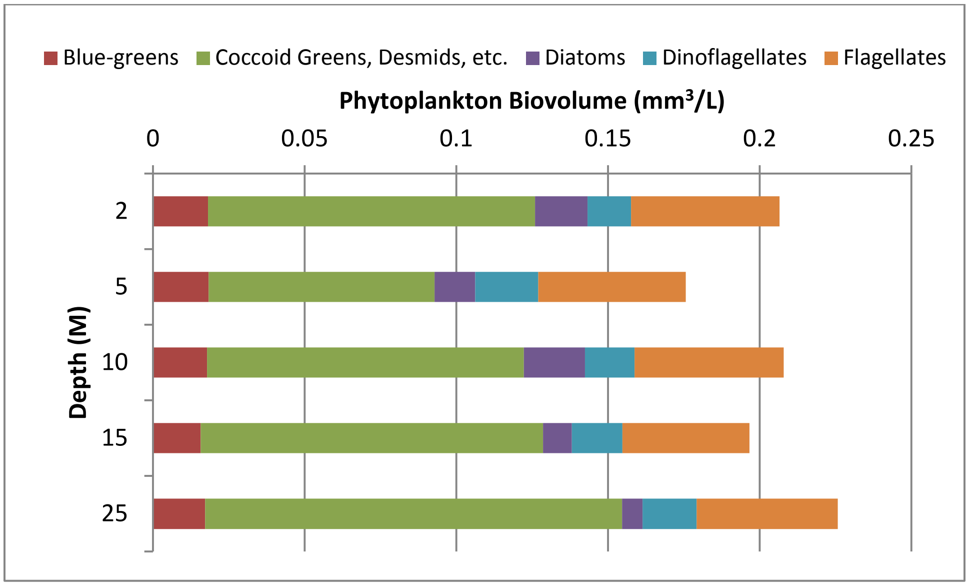
In Revelstoke there is little change in cell density with depth. The most abundant group at all depths were the blue-greens and flagellates. Dinoflagellate and diatoms were the least abundant groups (Figure 19).

Figure 19 Average phytoplankton density (Cells/mL), by depth, in Revelstoke Reservoir in 2015



The greatest average biovolume in Revelstoke Reservoir was at 25 meters. Flagellates, greens and blue-greens were the greatest contributors to the phytoplankton biovolume within in the system. Dinoflagellates and diatoms were the groups had the lowest average biovolumes (Figure 20).

Figure 20 Average phytoplankton biovolume (mm^3/L), by depth and group, in Revelstoke Reservoir in 2015



3.4 Phytoplankton in 2008-2015

To compare the 2008 through 2015 sampling seasons, phytoplankton cell counts and biovolume data from every sampling event at each station for the epilimnion samples were compiled.

Kinbasket

Inter-annual comparison of the average total density and total biovolume of phytoplankton suggests that there has been an increase in phytoplankton density since 2008(Table 10). This comparison may be misleading due to the temporal variability in the sampling as well as the tendency of phytoplankton communities to exhibit relatively large inter-annual variability (Figure 21 and Figure 22).

Table 9 Average seasonal phytoplankton density and biomass in Kinbasket Reservoir

Kinbasket	Year	Kin-Forebay	Canoe	Wood	Columbia	Reservoir Average
Average Density (Cells/mL)	2008	1672	1284	1276	1238	1368
	2009	2215	2066	2208	2110	2150
	2010	2797	3133	3075	2569	2893
	2011[ŧ]	2476	2717	5558	3586	3584
	2012	3823	4541	5522	4490	4594
	2013	5995	7838	7864	8885	7645

	2014	5999	7083	6953	7507	6886
	2015	7055	9227	7695	8958	7734
Biovolume (mm^3/L)	2008	0.19	0.13	0.16	0.16	0.16
	2009	0.26	0.22	0.23	0.18	0.22
	2010	0.14	0.14	0.16	0.12	0.14
	2011	0.09	0.07	0.1	0.07	0.08
	2012	0.09	0.08	0.13	0.12	0.11
	2013	0.17	0.18	0.25	0.19	0.2
	2014	0.18	0.19	0.17	0.21	0.19
	2015	0.28	0.27	0.26	0.37	0.3

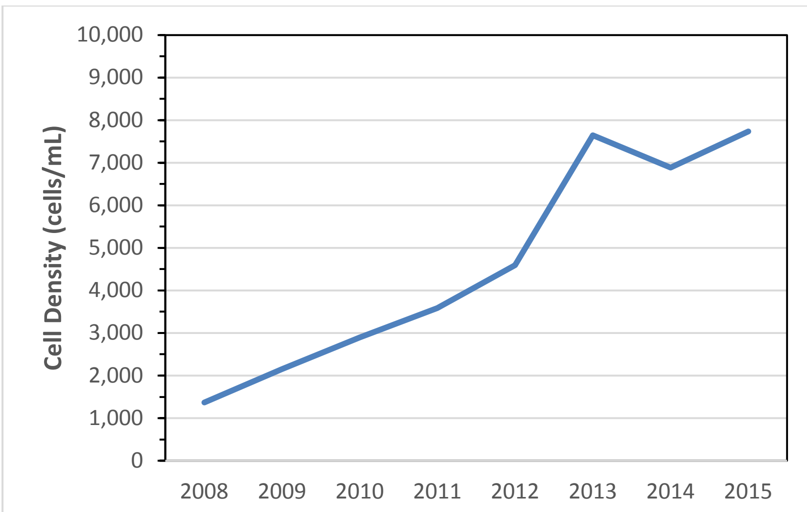


Figure 21 Mean epilimnetic phytoplankton density by year for Kinbasket

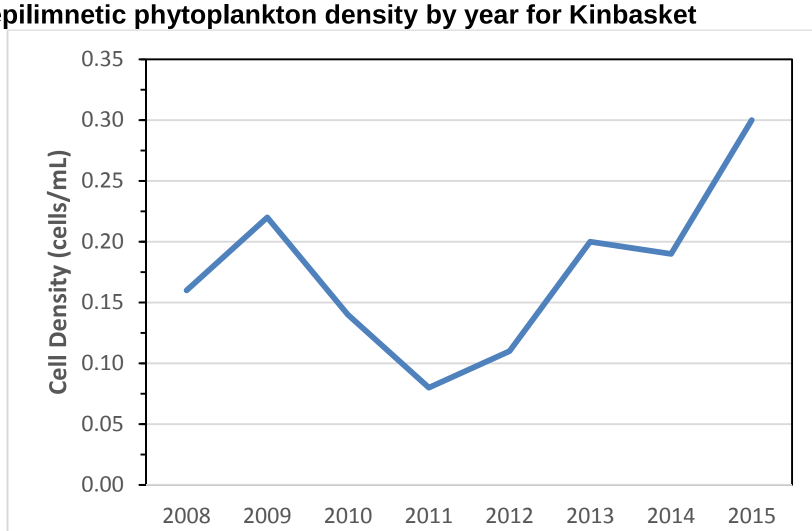


Figure 22 Mean epilimnetic phytoplankton biovolume by year for Kinbasket

Revelstoke

As observed in Kinbasket there is considerable intra and inter-annual variation in phytoplankton density and to a lesser extent in biovolumes within Revelstoke (Figure 23 and Figure 24). From 2008 through 2013 the means cell densities increased consistently (Table 10). The densities observed in 2014 and 2015 are slightly lower than 2013 but still considerably higher than 2008-2011 densities . The increasing mean densities are driven by high densities or Synechococcus and small micro-flagellate densities that occur in one or two months of the year.

Table 10 Average seasonal phytoplankton density and biomass in Revelstoke Reservoir

Revelstoke	Year	Forebay	Mid	Upper	Reservoir Average
Average Density (Cells/mL)	2008	2604	1829	1544	1992
	2009	2416	1901	1683	2000
	2010	1940	2502	1684	2375
	2011	3823	5143	4395	4154
	2012	5708	6425	7561	6565
	2013	7839	8328	12400	9523
	2014	6736	6949	6865	6850
	2015	7307	10194	7843	8448
Biovolume (mm^3/L)	2008	0.16	0.15	0.13	0.15
	2009	0.20	0.13	0.12	0.15
	2010	0.10	0.09	0.08	0.09
	2011	0.07	0.07	0.06	0.07
	2012	0.10	0.09	0.08	0.09
	2013	0.21	0.18	0.48	0.29
	2014	0.16	0.18	0.15	0.17
	2015	0.20	0.25	0.24	0.23

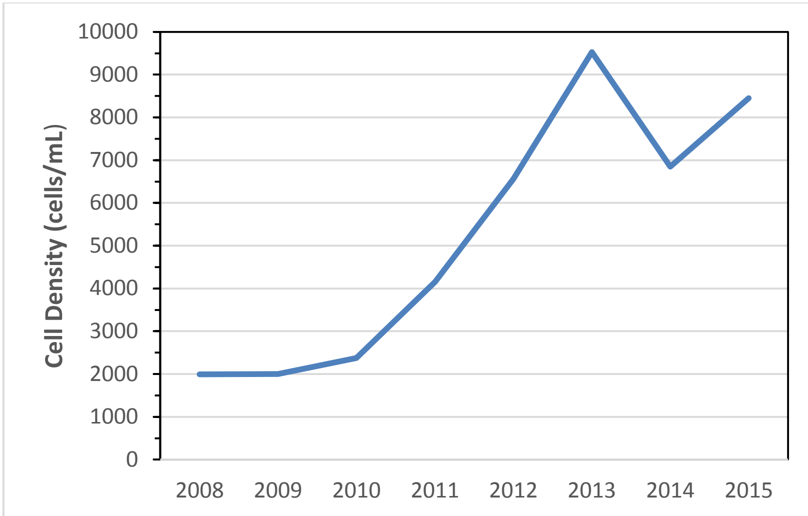


Figure 23 Mean epilimnetic phytoplankton density by year for Revelstoke

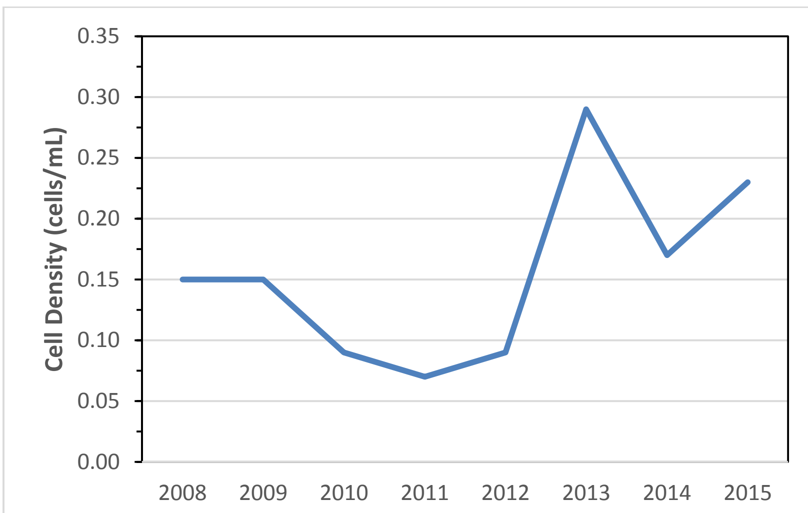


Figure 24 Mean epilimnetic phytoplankton biovolume by year for Revelstoke

3.5 Bacteria and Pico-cyanobacteria Density in 2015

3.5.1 Bacteria.

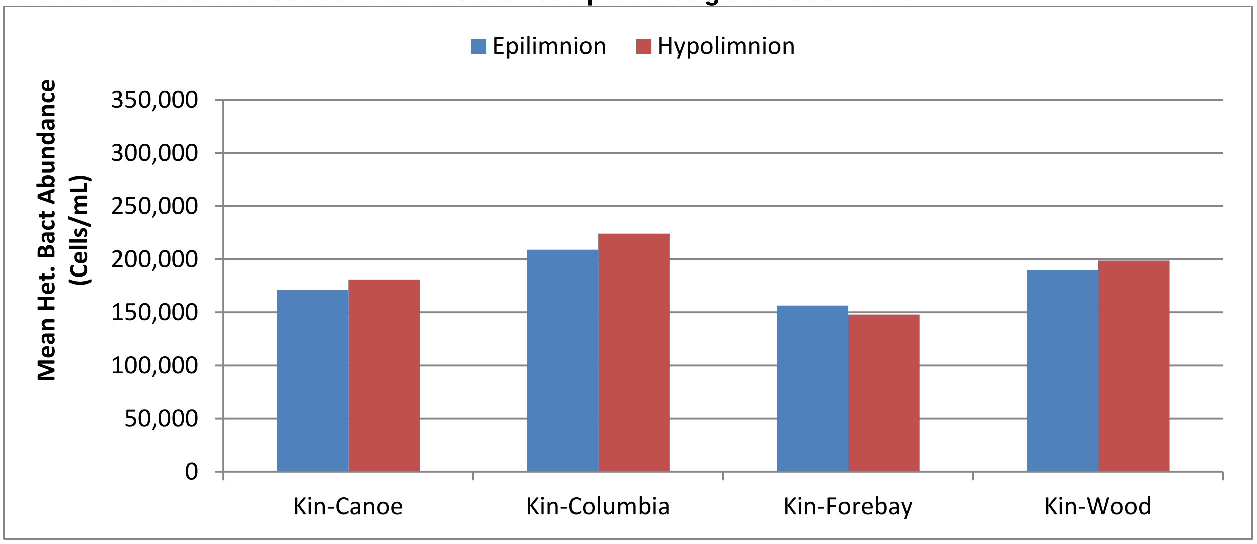
Kinbasket

Of the four stations, the Columbia station had the highest average epilimnetic densities. Mean reservoir heterotrophic bacteria numbers are lower than densities observed in 2013 and 2014 and are over 50% lower than those observed in 2012.

Table 10 2015 Picoplankton densities

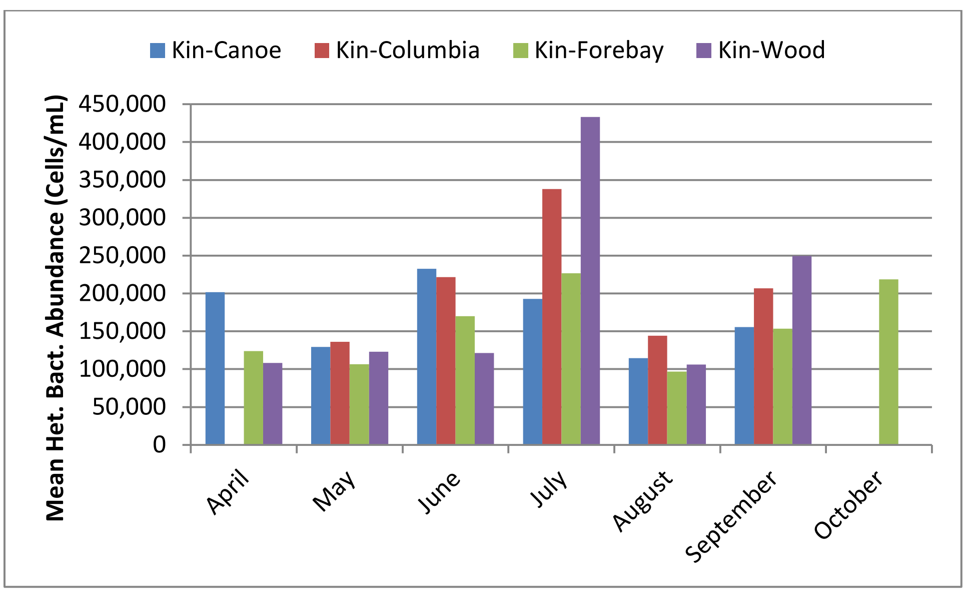
		Heterotrophic Bacteria (Cells/mL)							
		April	May	June	July	August	Sept.	Oct.	Avg.
Epilimnion	Kin-Canoe	201,684	129,554	232,483	192,742	114,453	155,783		171,117
	Kin-Columbia		136,112	221,554	337,795	144,060	206,651		209,234
	Kin-Forebay	123,991	106,505	169,891	226,522	96,702	153,399	218,573	156,512
	Kin-Wood	108,095	123,196	121,209	433,173	105,975	249,372		190,170
	Rev-Forebay	168,898	121,606	190,755	329,847	136,708	158,168	300,439	200,917
	Rev-Middle	160,950	596,109	224,535	349,718	101,339	195,524	325,873	279,150
	Rev-Upper	136,112	139,092	175,852	294,081	162,937	187,576	203,671	185,617
Hypolimnion	Kin-Canoe	203,671	158,963	253,346	181,813	135,118	152,604		180,919
	Kin-Columbia		138,099	237,450	389,458	131,939			224,236
	Kin-Forebay	153,001	104,120	118,228	152,008	118,560	165,321	224,932	148,024
	Kin-Wood	107,300	134,125	258,314	393,432	144,656	154,988		198,802
	Rev-Forebay	154,988	121,606	209,632	264,938	139,092	119,222		168,246
	Rev-Middle	183,800	150,021	244,405	323,224	163,731	216,984	386,478	238,378
	Rev-Upper	108,889	168,898	156,975	289,312	183,800	228,906	122,534	179,902
		Pico-cyano Bacteria (Cells/mL)							
		April	May	June	July	August	Sept.	Oct.	Avg.
Epilimnion	Kin-Canoe	7,286	6,458	36,263	37,091	22,354	13,744		20,533
	Kin-Columbia		3,477	37,754	40,182	26,659	5,464		22,707
	Kin-Forebay	6,458	3,312	44,708	55,968	38,858	11,591	9,604	24,357
	Kin-Wood	7,286	17,387	17,387	34,442	24,010	15,234		19,291
	Rev-Forebay	34,773	4,968	14,903	28,922	20,367	11,591	2,815	16,906
	Rev-Middle	8,776	5,299	5,961	23,348	5,299	8,279	4,968	8,847
	Rev-Upper	3,974	2,649	6,127	7,783	6,458	3,146	7,783	5,417
Hypolimnion	Kin-Canoe	7,451	8,445	29,805	33,780	17,552	9,273		17,718
	Kin-Columbia		5,299	42,721	11,922	17,883			19,456
	Kin-Forebay	4,636	7,948	26,825	46,364	23,182	13,744	13,081	19,397
	Kin-Wood	5,796	20,864	23,844	51,133	22,023	10,101		22,293
	Rev-Forebay	18,877	6,623	2,981	2,981	4,968	3,477		6,651
	Rev-Middle	3,974	6,127	5,464	9,107	6,292	6,789	4,802	6,079
	Rev-Upper	4,636	4,968	5,464	5,630	5,133	5,630	2,153	4,802

Figure 25 Average density (Cells/mL) of heterotrophic bacteria at four sampling stations in Kinbasket Reservoir between the months of April through October 2015



Reservoir heterotrophic bacteria densities peaked in July (Figure 26) followed by a noticeable reduction in August.

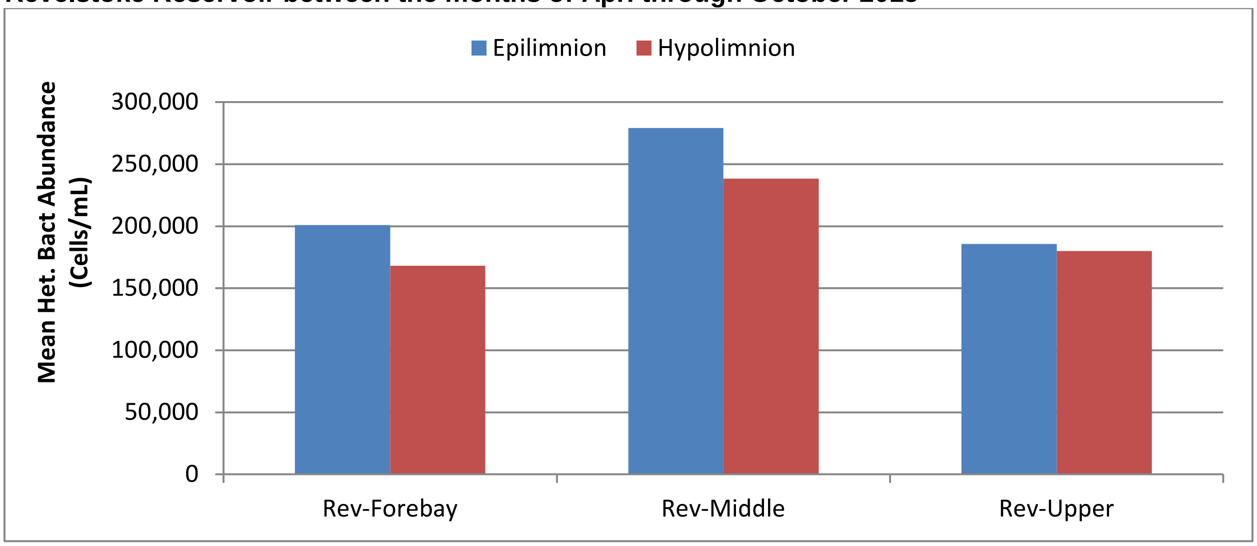
Figure 26 Kinbasket Reservoir monthly average density (Cells/mL) of epilimnetic heterotrophic bacteria at four sampling stations in 2015



Revelstoke

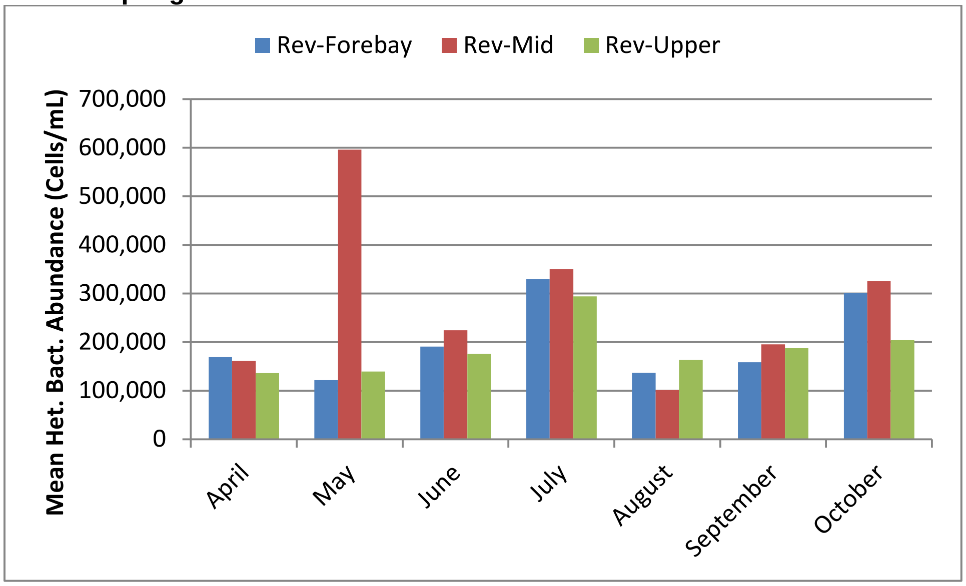
The epilimnetic average of heterotrophic bacteria ranged from 185,617 to 279,150 cells/mL (Table 10). These values are similar slightly lower thant those observed in Revelstoke in 2014 and approximately 50% lower than observed in Revelstoke in 2012. The Middle Station had the highest epilimnion and hypolimnion densities (Figure 27).

Figure 27 Average density (Cells/mL) of heterotrophic bacteria at three sampling stations in Revelstoke Reservoir between the months of Apri through October 2015



Reservoir mean heterotrophic bacteria densities peaked in July. There was a single sample at the Mid station in May that had density double of that of the next highest density observed (Figure 28).

Figure 28 Revelstoke Reservoir monthly average density (Cells/mL) of epilimnetic heterotrophic bacteria at three sampling stations in 2015



3.5.2 Pico-cyanobacteria.

Kinbasket

Total seasonal average density of epilimnetic pico-cyanobacteria in Kinbasket Reservoir was 21,722 cells/mL. All stations had relatively similar average epilimnetic densities (Table 10 and Figure 29). The densities observed in 2014 and 2015 were considerably lower than the densities observed in 2011 and in line with the 2010 and 2012, and 2013 densities.

The highest epilimnetic densities were observed in June and July. Hypolimnetic total seasonal average density of pico-cyanobacteria averaged 19,716 cells/mL (Figure 30).

Figure 29 Average density (Cells/mL) of pico-cyanobacteria at four sampling stations in Kinbasket Reservoir between the months of May through October 2015

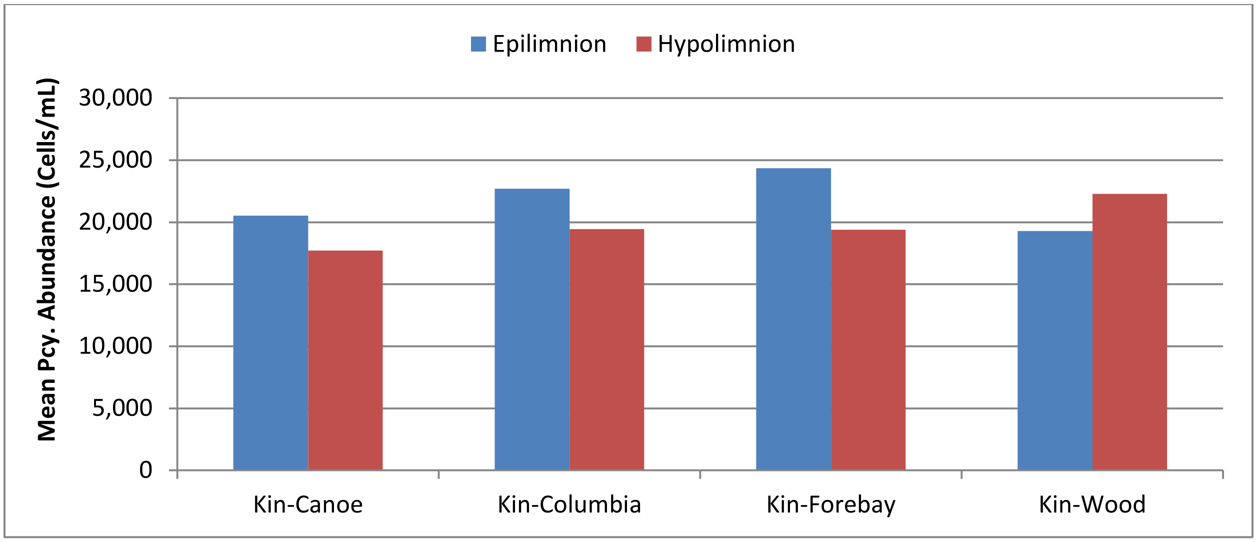
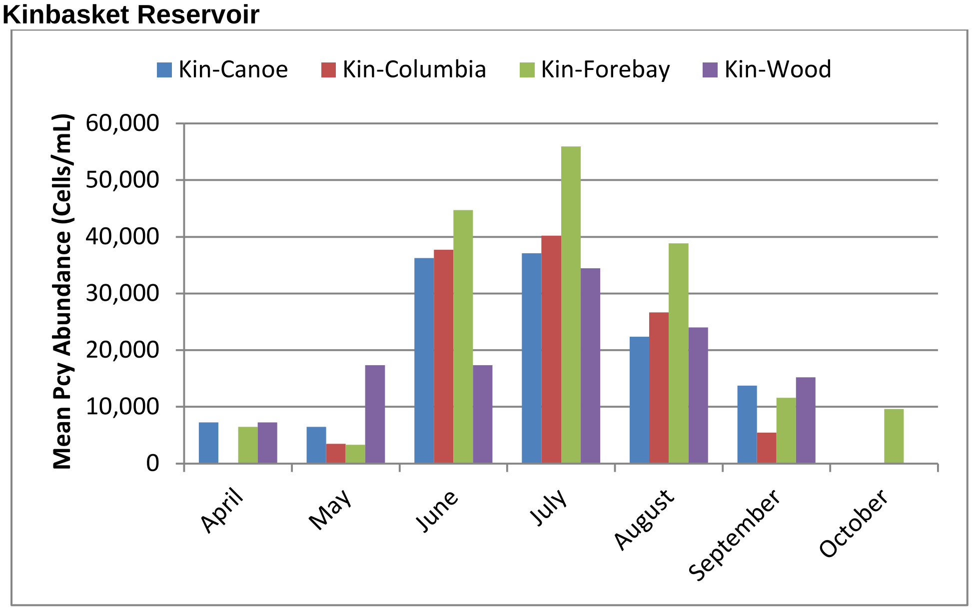


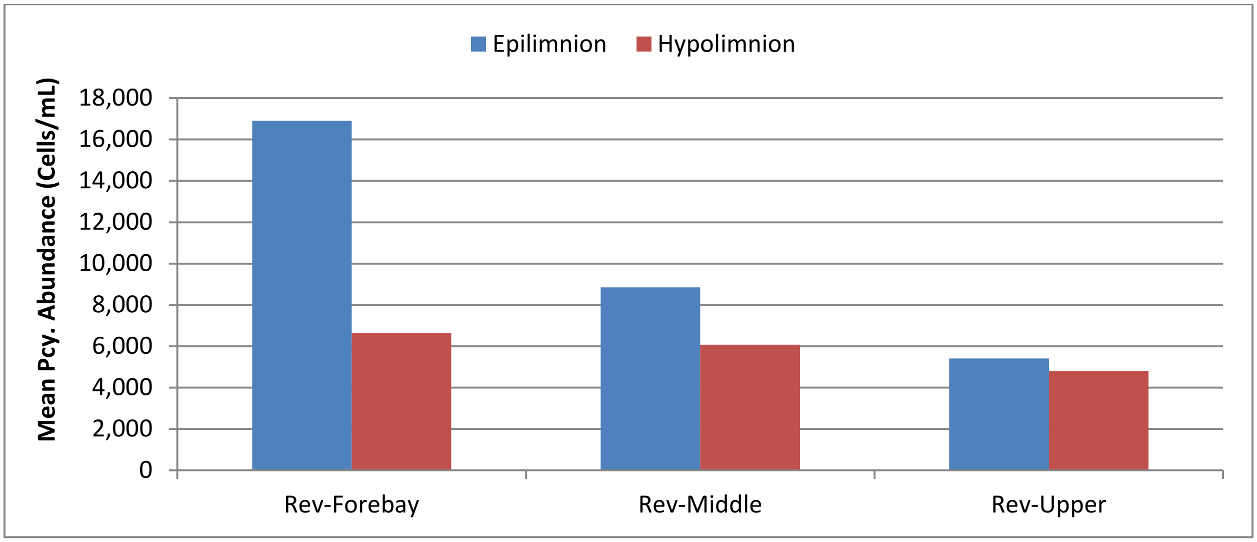
Figure 30 Average monthly density (Cells/mL) of epilimnetic pico-cyanobacteria at four sampling stations in Kinbasket Reservoir



Revelstoke

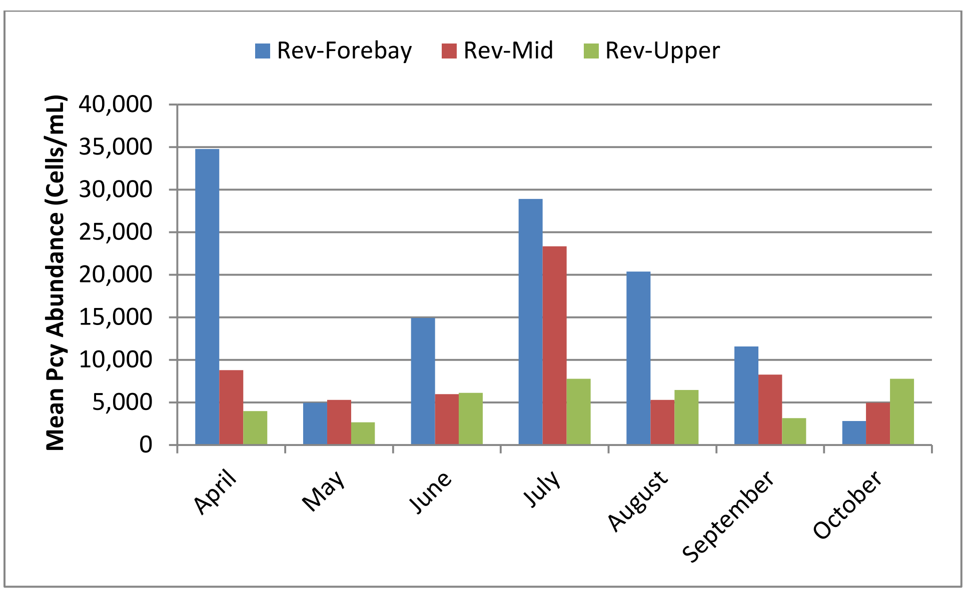
The average density in the epilimnion was approximately 10,390 cells/mL in Revelstoke Reservoir (Table 10). In the hypolimnion, the average density was 5,844 cells/mL. The Forebay station had the highest average density in the epilimnion but there was little difference in hypolimnetic densities between the three stations (Figure 31).

Figure 31 Average density (Cells/mL) of pico-cyanobacteria at three sampling stations in Revelstoke Reservoir between the months of May through October 2015



Following a April peak, the Forebay station exhibited a general increase in densities from June through August. The Middle and Upper stations were considerably less variable than the Forebay with the exception of a single samples in the Middle station in July (Figure 32).

Figure 32 Average monthly density (Cells/mL) of epilimnetic pico-cyanobacteria at three sampling stations in Revelstoke Reservoir



SECTION 4.0 SUMMARY

Based on phytoplankton density and biovolume, Kinbasket and Revelstoke Reservoirs fall within the oligotrophic classification. They both exhibit a typical temperate zone pattern of low phytoplankton density in the spring followed by a significant increase in mid-summer and a subsequent decline.

The increase in phytoplankton density with the concomitant decrease in biovolume indicates that the systems are becoming increasingly dominated by smaller taxa. This is a further indication that the systems are nutrient poor and that the total productivity of the system is likely declining. Additional examination of this apparent trend needs to be examined more closely. It may be the result of different sampling time frames or short time framed blooms of individual taxa rather than a temporal trend.

To better ascertain the trends within the system regarding productivity a comprehensive assessment of the nutrient concentrations, phytoplankton, zooplankton, and fish communities should be conducted. This information, in addition to the primary productivity measurements taken over the past few years, would provide an adequate set of data to determine overall system condition and allow for short term predictions of future conditions.

REFERENCES

Canter-Lund, H. and J.W.G. Lund. 1995. Freshwater Algae – their microscopic world explored. BioPress Ltd., Bristol, UK, 360p.

Lund J.G., C. Kipling, and E.D. LeCren. 1958. The Inverted Microscope Method of Estimating Algal Numbers and the Statistical Basis of Estimations by Counting. Hydrobiologia. 11: 143-170.

MacIsaac, E.R. and J.G. Stockner. 1993. Enumeration of phototrophic picoplankton by auto-fluorescence microscopy, p. 187-197. In: B. Sherr and E. Sherr [Eds.], The handbook of methods in aquatic microbial ecology, CRC Press, Boca Raton, Fl..

Pieters, R., L.C. Thompson, L. Vidmanic, S. Pond, J. Stockner, P. Hamblin, M. Young, K. Ashley, B. Lindsay, G. Lawrence, D. Sebastian, G. Scholten and D.L. Lombard. 1998. Arrow Reservoir Limnology and Trophic Status - Year 1 (1997/98) Report. Fisheries Project Report No. RD 67. Ministry of Environment, Lands and Parks, Province of British Columbia.

Pieters, R., L.C. Thompson, L. Vidmanic, M. Roushorne, J. Stockner, K. Hall, M. Young, S. Pond, M. Derham, K. Ashley, B. Lindsay, G. Lawrence, D. Sebastian, G. Scholten, F. McLaughlin, A. Wüest, A. Matzinger and E. Carmack. 1999. Arrow Reservoir Limnology and Trophic Status Report, Year 2 (1998/99). RD 72, Fisheries Branch, Ministry of Environment, Lands and Parks, Province of British Columbia.

Stockner, J. G., E. Rydin, and P. Hyehstrand. 2000. Cultural oligotrophication: Causes and consequences for fisheries resources. Fisheries 25(5):7-14.

Utermohl, H. 1958. Zur Vervollkommnung der Quantitativen Phytoplankton Methodik. Int. Verein. theor. angew. Limnologie, Mitteilung 9.

Appendix A.

Kinbasket and Revelstoke 2015 Taxa List and Number of Occurrences

Scientific Group Name	Common Group Name	Taxa	Kinbasket	Revelstoke
Bacillariophyte	Diatoms	Achnanthidium sp.	2	18
		Amphora (small)	2	2
		Asterionella formosa	3	2
		Aulacoseira granulata		1
		Aulacoseira italica		1
		Cocconeis sp.	1	2
		Cyclotella comta	35	10
		Cyclotella glomerata	85	55
		Cymbella sp. (large)		2
		Cymbella sp. (medium)	1	4
		Cymbella sp. (small)	1	6
		Diatoma sp.	1	7
		Eucocconeis flexella	1	1
		Fragilaria capucina	6	8
		Fragilaria crotonensis	4	
		Gomphonema sp. (medium)	1	3
		Hannaea arcus	1	1
		Navicula sp. (small)		1
		Nitzschia sp. (medium)	1	1
		Nitzschia sp. (small)	3	14
		Rhizosolenia sp.	2	1
		Staurosirella pinnata		1
		Stephanodiscus sp. (large)	31	17
		Stephanodiscus sp. (small)	12	3
		Synedra acus	85	59
		Synedra acus var. angustissima	16	22
		Synedra nana	2	2
		Synedra ulna	1	
Chlorophyte	Coccoid Greens, Desmids, Etc.	Acanthosphaera sp.	1	1
		Ankistrodesmus sp.	9	8
		Ankyra	2	2
		Aulomonas sp.	2	
		Carteria sp.	2	
		Chlamydocapsa sp.	45	20
		Chlamydomonas	34	22
		Coelastrum sp. (cells)	28	25
		Cosmarium sp.	35	19
		Dictyosphaerium (cells)	2	1
		Elakatothrix sp.	15	6
		Euglena	86	73
		Gleotila sp.	24	11
		Gloeococcus sp.	60	56
		Gloeocystis	9	4

Scientific Group Name	Common Group Name	Taxa	Kinbasket	Revelstoke
		Golenkinia sp.		2
		Monomastix sp.	89	84
		Monoraphidium	27	16
		Nephrocytium agardianum		2
		Nephroselmis	111	93
		Oocystis sp. (cells)	101	85
		Paramastix	6	4
		Phacus (large)	2	2
		Phacus (medium)	29	23
		Phacus (small)	53	53
		Planktosphaeria	5	1
		Polytomella		1
		Scenedesmus sp.	9	4
		Scourfieldia	109	99
		Sphaerocystis sp.	2	
		Staurastrum sp. (large)	1	
		Staurastrum sp. (small)		1
		Stichococcus minutissimus		1
		Tetraedron	122	106
		Treubaria sp.		2
Chryso- & Cryptophyte	Flagellates	Bitrichia sp.	1	
		Chromulina sp.	66	52
		Chroomonas acuta	119	106
		Chrysochromulina sp.	10	11
		Chrysococcus	99	66
		Chrysolykos sp.	2	2
		Codonomonas sp.		1
		Cryptomonas sp. (large)	10	9
		Cryptomonas sp. (medium)	85	80
		Cryptomonas sp. (small)	62	49
		Cyathomonas truncata	1	
		Dinobryon sp. (medium)	54	36
		Dinobryon sp. (small)	1	11
		Dylakosoma sp.	1	
		Gyromitus sp.	27	15
		Kephyrion sp.	93	78
		Komma sp.	105	91
		Mallomonas sp. (large)	3	4
		Mallomonas sp. (medium)	47	46
		Mallomonas sp. (small)	49	49
		Ochromonas sp.	94	77
		Pseudokephrion sp.	108	89
		Small microflagellates	124	105

Scientific Group Name	Common Group Name	Taxa	Kinbasket	Revelstoke
		Sphaleromantis sp	1	
		Stenokalyx	1	
		Trachelomonas sp.	76	45
Cyanophyte	Blue-Greens	Anabaenopsis sp.		1
		Aphanothece minutissimus	20	28
		Chroococcus sp. (cells)	63	52
		Merismopedia sp. (cells)	57	51
		Microcystis sp. (cells)	3	2
		Planktothrix rubescens	1	
		Synechococcus sp. (coccoid)	119	104
		Synechococcus sp. (rod)	120	106
		Synechocystis	96	77
Dinophyte	Dinoflagellates	Amphidinium	99	84
		Gloeodinium sp.	1	1
		Gymnodinium sp. (large)	7	10
		Gymnodinium sp. (medium)	83	65
		Gymnodinium sp. (small)	74	70
		Peridinium spp.	3	1

Appendix 7

Zooplankton
Kinbasket and Revelstoke Reservoirs, 2015

Lidija Vidmanic
Limno Lab

Table of Contents

List of Figures

List of Tables

1. Introduction

This report summarises the zooplankton data collected in 2015, with comparisons to available data from previous years and some historical data. The study of Kinbasket and Revelstoke Reservoirs macrozooplankton (length >150 µm), including their composition, abundance and biomass help to determine the current status of reservoirs. These results are a component of the study CLBMON-3 Kinbasket and Revelstoke Reservoirs Ecological Productivity conducted by BC Hydro under the Columbia Water Use Plan.

2. Methods

Samples were collected monthly at four stations in Kinbasket Reservoir during the highest production season. The Kinbasket sampling stations are located at Mica Forebay, Canoe Reach, Wood Arm and Columbia Reach.

In Revelstoke Reservoir samples were collected at three stations. The stations Rev Upper, Rev Middle, and Rev Forebay are located along the length of the main body in Revelstoke Reservoir.

Samples were collected from April to October in both reservoirs during 2015 sampling season, with a vertically hauled 153 µm mesh Wisconsin net with a 0.2 m throat diameter. The depth of each haul was 30 m. Duplicate samples were taken at each site of the reservoir. Due to a technical problem samples could not be collected in Kinbasket reservoir from stations Columbia Reach in April and from Canoe Reach, Columbia Reach and Wood Arm in October 2015.

Collected zooplankton samples were rinsed from the dolphin bucket and preserved in 70% ethanol. Zooplankton samples were analyzed for species density, biomass, and fecundity. Samples were re-suspended in tap water filtered through a 74 µm mesh and sub-sampled using a four-chambered Folsom-type plankton splitter. Splits were placed in gridded plastic petri dishes and stained with Rose Bengal to facilitate viewing with a Wild M3B dissecting microscope. For each replicate, organisms were identified to species level and counted until up to 200 organisms of the predominant species were recorded. If 150 organisms were counted by the end of a split, a new split was not started. The lengths of up to 30 organisms of each species were measured for use in biomass calculations, using a mouse cursor on a live television image of each organism. Lengths were converted to biomass (µg dry-weight) using empirical length-weight regression from McCauley (1984). The number of eggs carried by gravid *Daphnia* females and the lengths of these individuals were recorded for use in fecundity estimations. Zooplankton species were identified with reference to taxonomic keys (Sandercock and Scudder 1996, Pennak 1989, Wilson 1959, Brooks 1959).

3. Results – Kinbasket Reservoir

3.1 Species Present

Four calanoid copepod species were identified in the samples from Kinbasket Reservoir (Tab. 1). *Leptodiaptomus sicilis* (Forbes) and *Epischura nevadensis* (Lillj.) were present in samples during each sampling season, while *Leptodiaptomus ashlandi* (Marsh) and *Aglaodiaptomus leptopus* (Forbes) were observed rarely. One cyclopoid copepod species, *Diacyclops bicuspidatus thomasi* (Forbes), was seen in samples during the studied period.

Table 1. List of zooplankton species identified in Kinbasket Reservoir in 2003-2015. "+" indicates a consistently present species and "r" indicates a rarely present species.

	2003	2004	2005	2008	2009	2010	2011	2012	2013	2014	2015
Cladocera											
Alona sp.						r			r		r
Bosmina longirostris	+	+	+	+	+	+	+	+	+	+	+
Chydorus sphaericus			+		+	+			r		
Daphnia galeata mendotae	+	+	+	+	+	+	+	+	+	+	+
Daphnia rosea	+	+	+	+	+	+	+	+	+	+	+
Daphnia schoedleri	+	+	+	+	+	+	+	+	+	+	+
Diaphanosoma brachyurum		+	+		+	+		+	+	+	+
Holopedium gibberum	r			r	r	r				r	r
Leptodora kindtii	+	+	+	+		+	+	+	+	+	+
Macrothrix sp.					r						
Scapholeberis rammneri	+	+	+	+	+	+	+	+	+	+	+
Copepoda											
Aglaodiaptomus leptopus		r		r					r	r	r
Diacyclops bicuspidatus	+	+	+	+	+	+	+	+	+	+	+
Epischura nevadensis	+	+	+	+	+	+	+	+	+	+	+
Leptodiaptomus ashlandi		r	r		r	r	r	r	r	r	r
Leptodiaptomus sicilis	+	+	+	+	+	+	+	+	+	+	+

Nine species of Cladocera were present in 2015 (Tab. 1). *Daphnia galeata mendotae* (Birge), *Daphnia schoedleri* (Sars), *Daphnia rosea* (Sars), *Bosmina longirostris* (O.F.M.) *Diaphanosoma brachyurum* (Lievin), *Scapholeberis rammneri* (Dumont and Pensaert) and *Leptodora kindtii* (Focke) were common, while other species were observed sporadically. *Daphnia* spp. were not identified to species for density counts.

The predominant copepods *D. bicuspidatus thomasi* and *E. nevadensis*, and cladocerans *Daphnia* spp., and *B. longirostris* were common during studied years.

3.2 Density and Biomass

For comparison with historical data the average at Mica Forebay station in Kinbasket was used. Zooplankton density values from 2003 to 2015 are significantly higher than those reported by the Division of Applied Biology, BC Research in 1977, Watson 1985 and Fleming and Smith 1988 (Fig. 1).

The seasonal average zooplankton density in Kinbasket Reservoir decreased in 2015 to 6.34 individuals/L from 7.72 individuals/L in 2014 (Fig. 2). The zooplankton density was numerically dominated by copepods, which averaged 79% of the 2015 community with 5.01 individuals/L. *Daphnia* spp comprised 7% with 0.42 individuals/L, and other cladocerans 14% with 0.90 individuals/L.

The average zooplankton densities for all four sampling stations in Kinbasket Reservoir fluctuated over the course of the studied period. It increased from 0.45 individuals/L in April to 13.70 individuals/L in June, and then gradually decreased to 2.01 individuals/L at the end of the sampling season (Tab. 2).

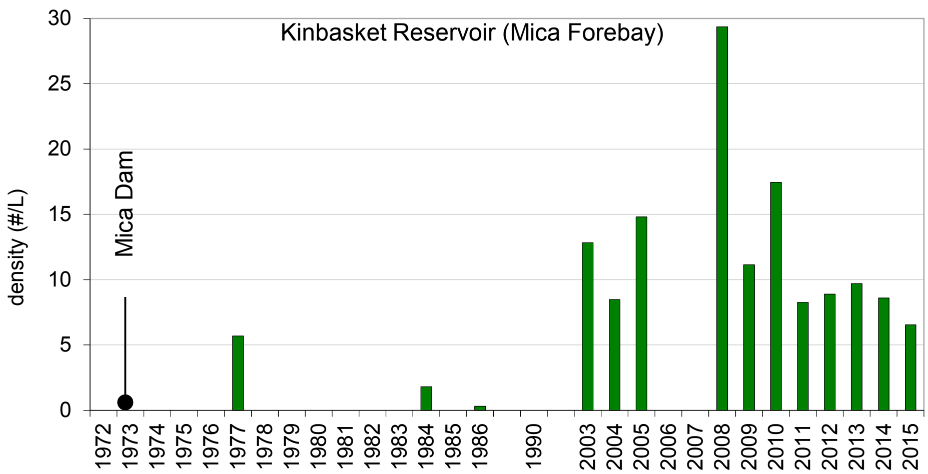


Figure 1. Zooplankton density 1977-2015 at Mica Forebay in Kinbasket Reservoir

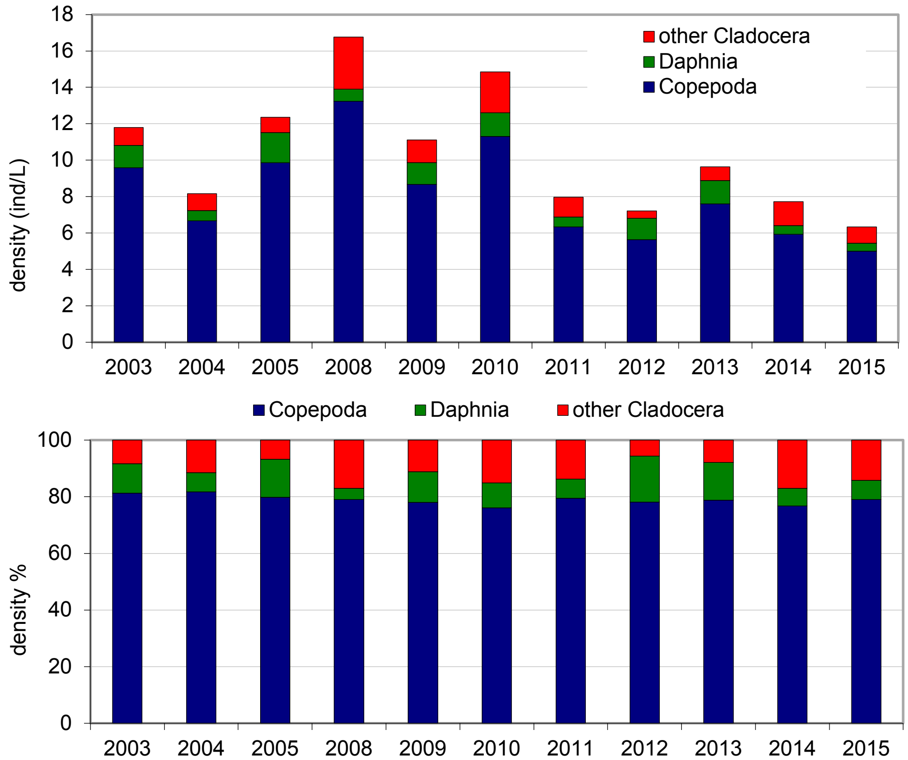


Figure 2. Seasonal average zooplankton density in Kinbasket Reservoir 2003-2015

Table 2. Monthly average density and biomass of zooplankton in Kinbasket Reservoir in 2015. Density is in units of individuals/L, and biomass is in units of µg/L.

Density		13-Apr	11-May	15-Jun	14-Jul	23-Aug	21-Sep	13-Oct
	Copepoda	0.32	3.23	11.70	10.13	3.11	1.42	0.95
	Daphnia	0.01	0.04	0.25	0.35	0.88	0.89	0.54
	Other Cladocera*	0.12	0.19	1.75	2.16	0.48	0.63	0.52
	Total Zooplankton	**0.45**	**3.45**	**13.70**	**12.64**	**4.47**	**2.94**	**2.01**
Biomass		13-Apr	11-May	15-Jun	14-Jul	23-Aug	21-Sep	13-Oct
	Copepoda	0.44	6.03	16.44	16.22	6.88	3.61	1.76
	Daphnia	0.14	0.50	3.38	4.31	15.04	20.82	7.51
	Other Cladocera**	0.48	0.60	3.90	4.48	1.52	2.09	2.02
	Total Zooplankton	**1.06**	**7.13**	**23.72**	**25.01**	**23.44**	**26.52**	**11.30**

*Values do not include *Daphnia* spp. density.
**Values do not include *Daphnia* spp. biomass.

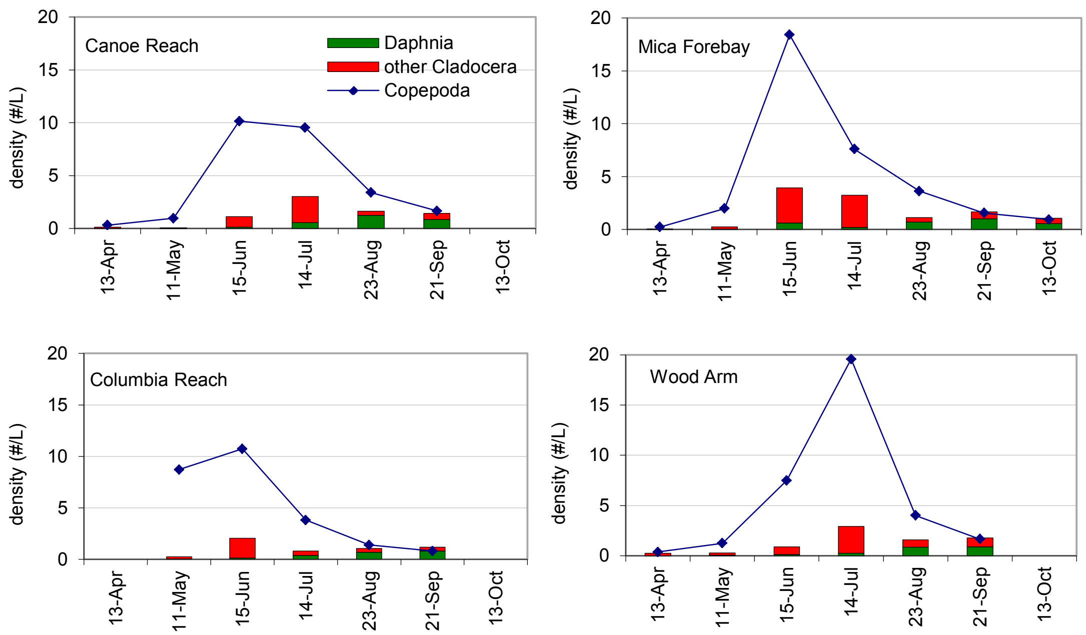


Figure 3. Density of cladoceran and copepod zooplankton at four stations in Kinbasket Reservoir 2015

Copepods were the most abundant zooplankton at all four stations. They numerically prevailed during the whole sampling season, with populations peaking in June-July. The highest copepod density was found in July at station Wood Arm with 19.57 individuals/L. (Fig. 3). The number of Cladocerans, mostly *Bosmina,* varied by season as well as along the reservoir. Cladocerans other than *Daphnia* were the most numerous in June-July at each sampling station. The highest density was found in June at Mica Forebay with 3.33 individuals/L. *Daphnia* was present during the whole sampling season at each station. Monthly averaged density of *Daphnia* for the whole reservoir increased gradually during the sampling season reaching its peak in September with 0.89 individuals/L (Fig.4). The highest density of *Daphnia* was found in August at Canoe Reach with 1.24 individuals/L. The proportion of *Daphnia* density was the highest at Canoe Reach (8%), while at other stations it varied between 5 and 7%. (Tab. 3, Fig. 5)

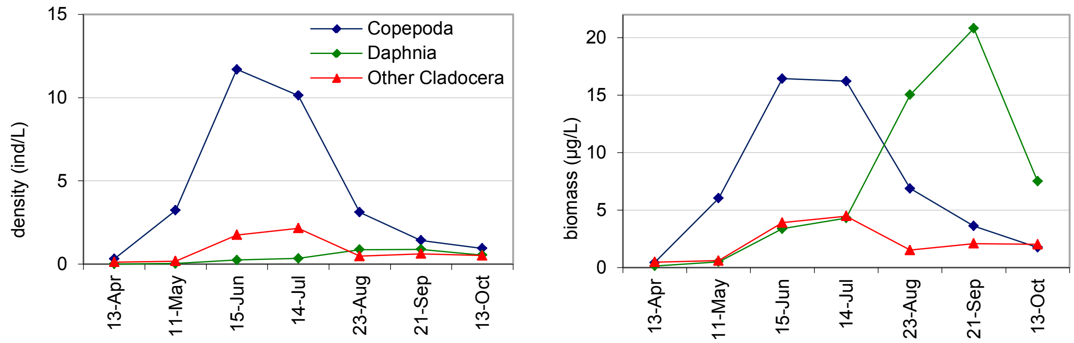


Figure 4. Monthly zooplankton density and biomass averaged for the whole Kinbasket Reservoir 2015

Table 3. Seasonal average zooplankton density and biomass at four sampling stations in Kinbasket Reservoir in 2015. Density is in units of individuals/L; biomass is in units of µg/L.

		Canoe Reach	**Mica Forebay**	**Columbia Reach**	**Wood Arm**
Density	Copepoda	4.34	4.91	5.09	5.73
	Daphnia	0.47	0.45	0.40	0.37
	Other Cladocera	0.76	1.17	0.66	0.93
	Total	**5.58**	**6.53**	**6.15**	**7.02**
Biomass	Copepoda	7.47	7.71	9.47	8.95
	Daphnia	9.23	6.89	7.77	6.93
	Other Cladocera	2.39	2.83	1.09	2.37
	Total	**19.10**	**17.43**	**18.33**	**18.25**

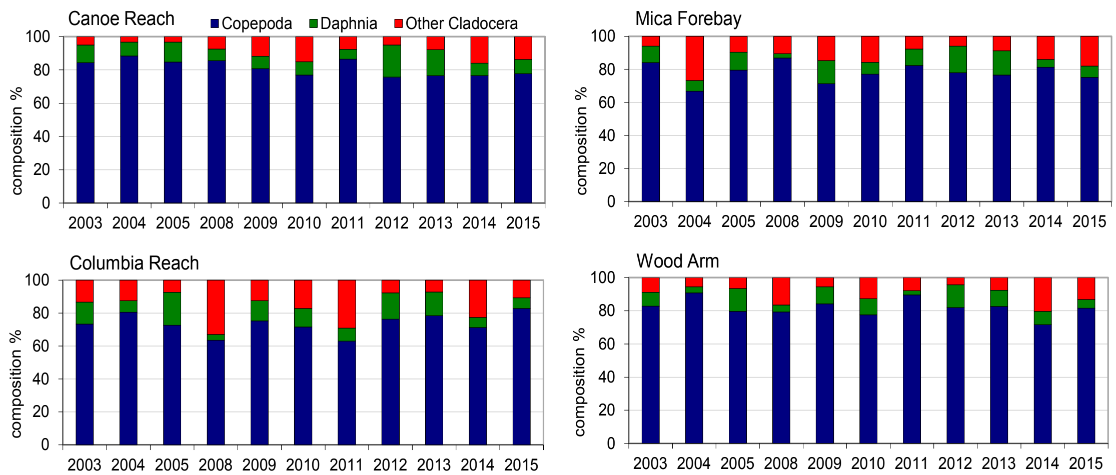


Figure 5. Seasonal average % of zooplankton density composition at four stations in Kinbasket Reservoir in 2003-2015

Total zooplankton biomass, averaged for the whole reservoir, was 18.24 µg/L Copepods contributed to 46% of the total zooplankton biomass with annual average biomass of 8.33 µg/L. *Other Cladocera* had average biomass 2.24 µg/L which comprised 12%, while *Daphnia* made up to 42% of the total zooplankton biomass with 7.67 µg/L (Fig. 6). Average zooplankton biomass for the four stations was low at the beginning of the sampling season. During the rest of the sampling season zooplankton biomass increased reaching its peak in September with 26.52 µg/L, dominated by *Daphnia* with 20.82 µg/L, which made up 78% of the total biomass at that time (Tab. 2).

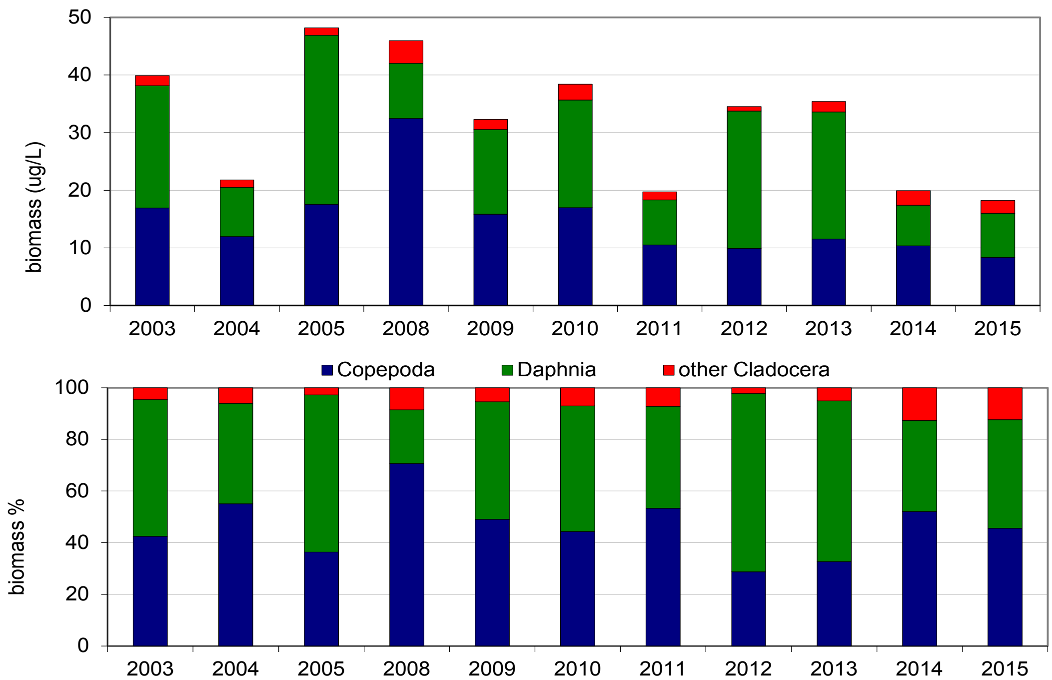


Figure 6. Seasonal average zooplankton biomass in Kinbasket Reservoir 2003-2015

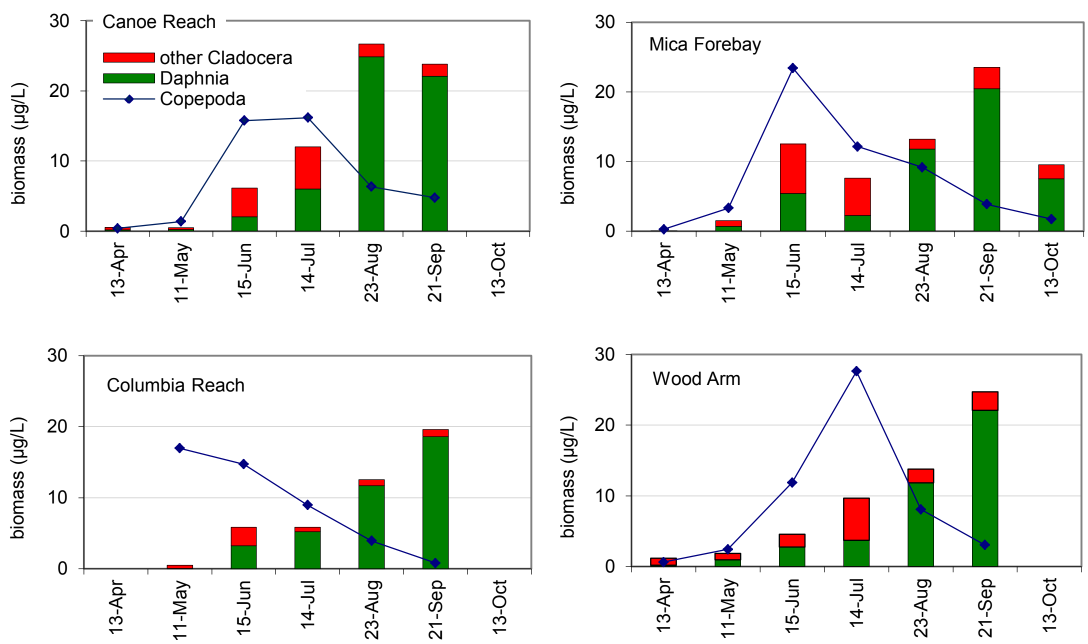


Figure 7. Zooplankton biomass at four stations in Kinbasket Reservoir 2015

Daphnia density increased over the course of the study in Kinbasket Reservoir. Although *Daphnia* were present in the samples during the entire season, they accounted for the highest proportion of zooplankton biomass in September and October (Fig. 7). *Daphnia* density in 2015 was the lowest at station Wood Arm averaging 0.37 individuals/L contributing to 5% of zooplankton density, while biomass was the lowest at station Mica Forebay with 6.89 µg/L which made up 38% of total zooplankton biomass. During the same time period the highest annual average *Daphnia* density and biomass were found at station Canoe Reach with 0.47 individuals/L and 9.23 µg/L when contributed to 8% of the zooplankton density and 48% of the zooplankton biomass (Tab. 2,Fig. 5, Fig.8, Fig. 9).

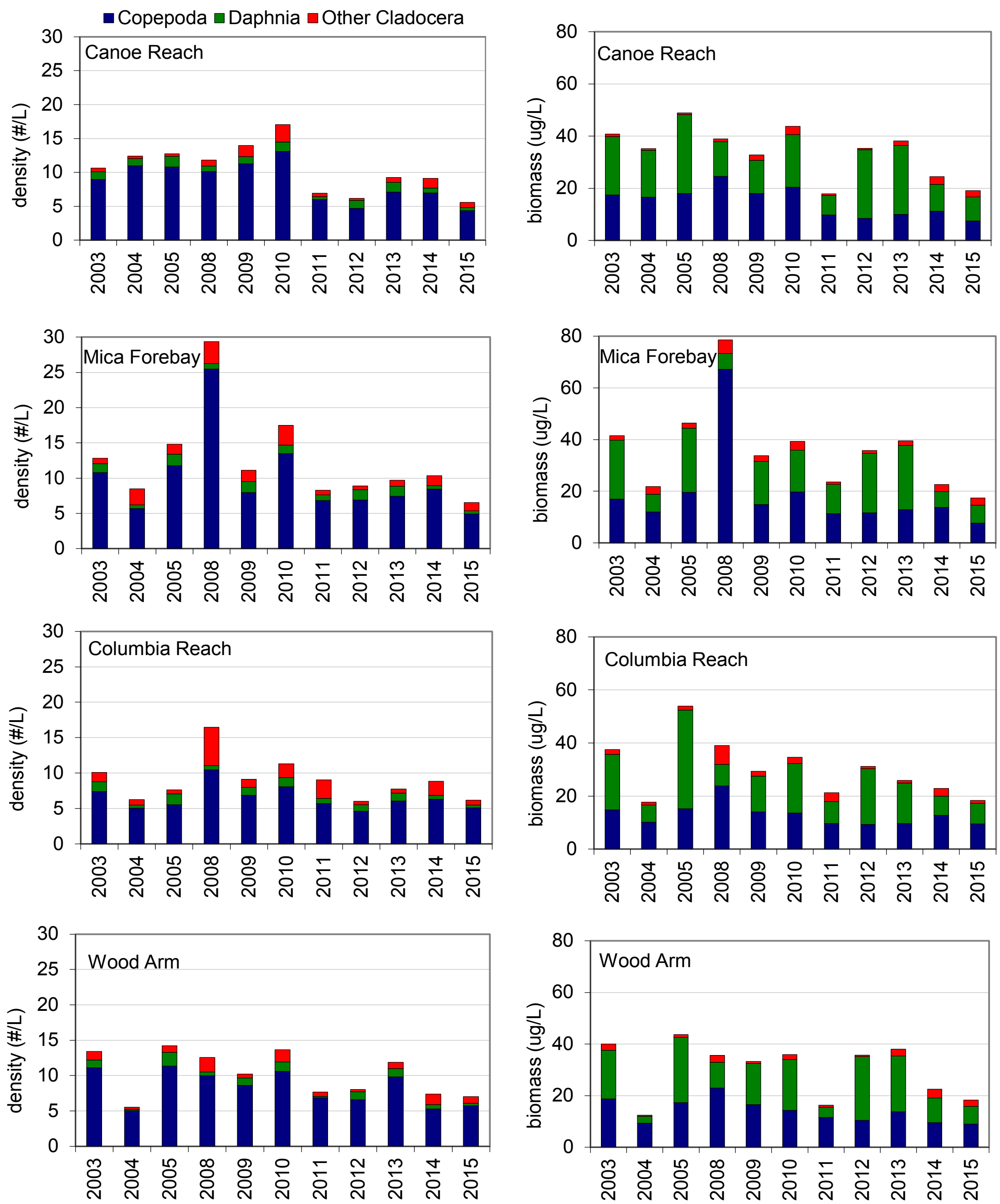


Figure 8. Annual average zooplankton density (left) and biomass (right) at four stations in Kinbasket Reservoir 2003-2015

In 2015 peak total zooplankton density occurred in July at 12.64 individuals/L while the highest biomass was found in September with 26.52 µg/L (Tab. 2, Fig. 4). *Daphnia* was the most numerous in September with 0.89 individuals/L, and the highest biomass of 20.82 µg/L.

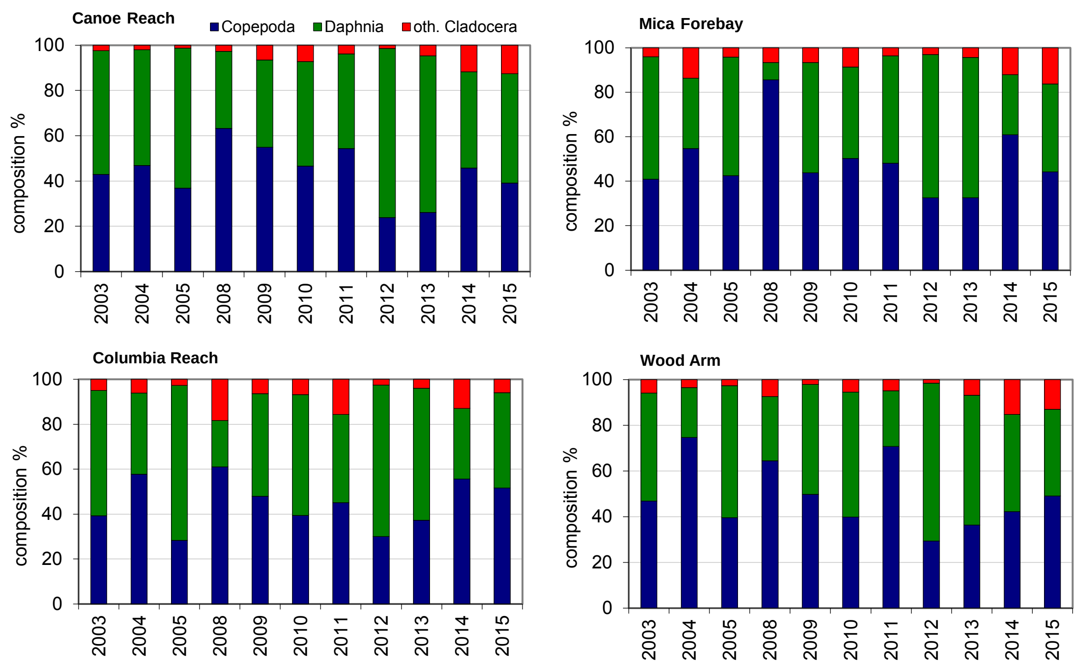


Figure 9. Seasonal average % of zooplankton biomass composition at four stations in Kinbasket Reservoir in 2003-2015

In comparison to data from the previous year, total zooplankton biomass decreased in 2015 to 18.24 µg/L from 19.95 µg/L in 2014 (Fig. 6).

3.3 *Daphnia* Fecundity

In Kinbasket Reservoir *Daphnia* gravid females were present in samples during the entire sampling season 2015. The proportion of gravid females averaged 0.30 (Tab. 4). The seasonal average number of eggs per gravid female was 1.97. Across the sampling season the number of eggs per water volume averaged 0.22 eggs/L and the number of eggs per capita averaged 0.58 eggs/individual.

Table 4. Fecundity data for *Daphnia* spp. in Kinbasket Reservoir in 2015. Values are seasonal averages, calculated for samples collected between April and October 2015.

	2015
Proportion of gravid females	0.30
# Eggs per gravid Female	1.97
# Eggs per Litre	0.22
# Eggs per Capita	0.58

4. Results – Revelstoke Reservoir

4.1 Species Present

Three calanoid copepod species were identified in the samples from Revelstoke Reservoir (Tab. 5). *Leptodiaptomus sicilis* (Forbes) and *Epischura nevadensis* (Lillj.) were present in samples during the whole season while *Leptodiaptomus ashlandi* (Marsh) was observed occasionally. One cyclopoid copepod species, *Diacyclops bicuspidatus thomasi* (Forbes), was seen in samples from Revelstoke Reservoirs.

Eleven species of Cladocera were identified in Revelstoke Reservoir during the study period in 2015 (Tab. 6). *Daphnia galeata mendotae* (Birge), *Daphnia pulex* (Leydig), *Daphnia rosea* (Sars), *Bosmina longirostris* (O.F.M.), *Holopedium gibberum* (Zaddach) and *Leptodora kindtii* (Focke) were common during the entire sampling season, while others were observed sporadically. *Daphnia* spp. were not identified to species for density counts.

The predominant copepod was *D. bicuspidatus thomasi*, while *Daphnia* spp., and *B. longirostris* were the most numerous among the cladocerans

4.2 Density and Biomass

The seasonal average zooplankton densities observed in 2003, 2008-2015 were much higher than those reported for years 1984 and 1986 by Watson 1985 and Fleming and Smith 1988 (Fig. 10). For comparison with historical data the average at Rev Forebay in Revelstoke Reservoir was used.

Table 5. List of zooplankton species identified in Revelstoke Reservoir in 2003-2015. "+" indicates a consistently present species and "r" indicates a rarely present species.

	2003	2008	2009	2010	2011	2012	2013	2014	2015
Cladocera									
Acroperus harpae	r								
Alona sp.	r			r	r	r			r
Alonella nana				r					
Biapertura affinis	r	r							
Bosmina longirostris	+	+	+	+	+	+	+	+	+
Ceriodaphnia sp.		r							
Chydorus sp.	r								
Chydorus sphaericus	r	r		r	r				r
Daphnia galeata mendotae	+	+	+	+	+	+	+	+	+
Daphnia rosea	+	+	+	+	+	+	+	+	+
Daphnia pulex	+	+	+	+	+	+	+	+	+
Diaphanosoma brachyurum			r			r	r		r
Holopedium gibberum	+	+	+	+	+	+	+	+	+
Ilyocryptus sp.									r
Leptodora kindtii	+	+	+	+	+	+	+	+	+
Scapholeberis rammneri	r	r	r	r	r	r	+	+	r
Copepoda									
Diacyclops bicuspidatus	+	+	+	+	+	+	+	+	+
Epischura nevadensis	+	+	+	+	+	+	+	+	+
Leptodiaptomus ashlandi	+	+	+	+	+	+	+	+	+
Leptodiaptomus sicilis	+	+	+	+	+	+	+	+	+

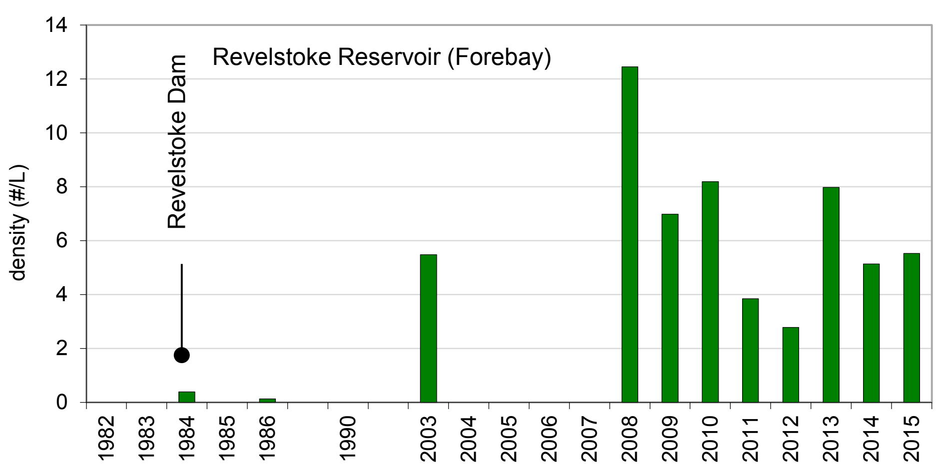


Figure 10. Zooplankton density 1984-2015 at Rev Forebay in Revelstoke Reservoir

The zooplankton community was primarily composed of copepods, which made up 74% of the zooplankton density and 30% of the zooplankton biomass during the studied period in 2015. *Daphnia* accounted for 10% of the density and 57% of the biomass during the same time period, while other cladocerans comprised 16% of density and 12% of zooplankton biomass (Fig. 11 and 12).

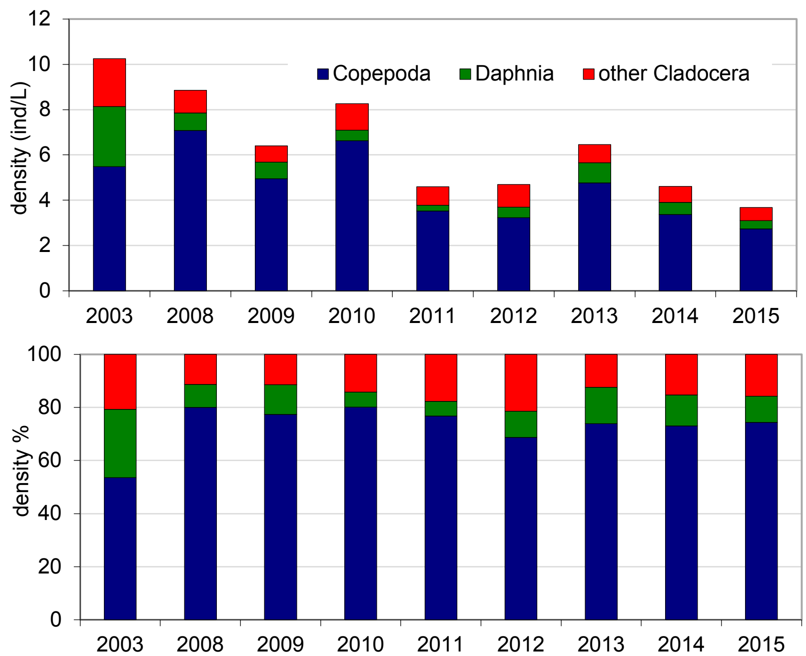


Figure 11. Seasonal average composition of zooplankton density in Revelstoke Reservoir in 2003, 2008 – 2015

The seasonal average zooplankton density in 2015 (April to October) decreased to 3.68 individuals/L from 4.62 individuals/L in 2014. Copepods were the most abundant with 2.74 individuals/L. Annual average density of *Daphnia* was 0.36 individuals/L, while density of other Cladocera (mainly *Bosmina* and *Holopedium*) was 0.58 individual/L. (Tab. 7, Fig. 11). Total zooplankton biomass, averaged for the whole reservoir was 14.90 µg/L. Copepods annual average biomass was 4.52 µg/L, while *Daphnia* and other cladocerans biomass was 8.52 µg/L, and 1.85 µg/L respectively (Tab. 7; Fig. 12).

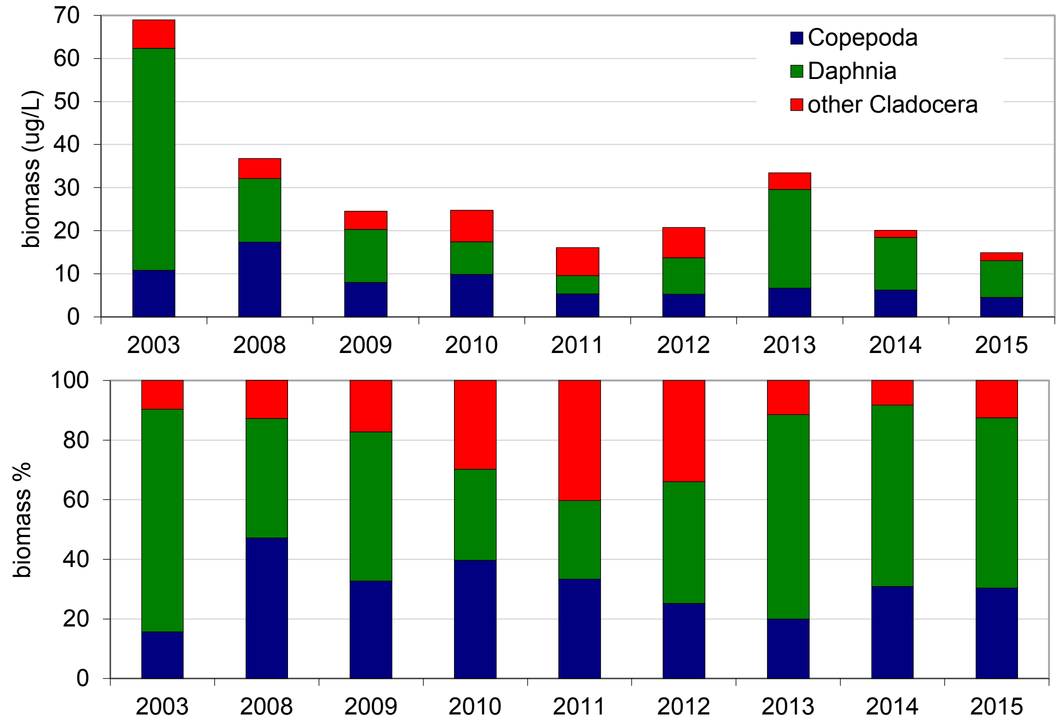


Figure 12. Seasonal average composition of zooplankton biomass in Revelstoke Reservoir in 2003, 2008 – 2015

Table 6. Annual average zooplankton abundance and biomass in Revelstoke Reservoir 2015 (April to October).

		ind/L	%
Density	Copepoda	2.74	74
	Daphnia	0.36	10
	other Cladocera	0.58	16
	Total	**3.68**	

		µg/L	%
Biomass	Copepoda	4.52	30
	Daphnia	8.52	57
	other Cladocera	1.87	13
	Total	**14.90**	

The seasonal average zooplankton densities in Revelstoke Reservoir decreased in comparison to the previous year. The highest zooplankton density averaged for the whole reservoir was in June with 8.15 individuals/L (Fig. 13). Seasonal average zooplankton biomass in 2015 also decreased in comparison to the previous year (Tab. 6). The highest zooplankton biomass averaged for the whole reservoir was found in August with 22.28 µg/L. Among the stations, the highest total zooplankton density was seen at Rev Forebay in June with 15.32 individuals/L, while the highest biomass was found in October at station Rev Middle with 49.89 µg/L (Fig. 14).

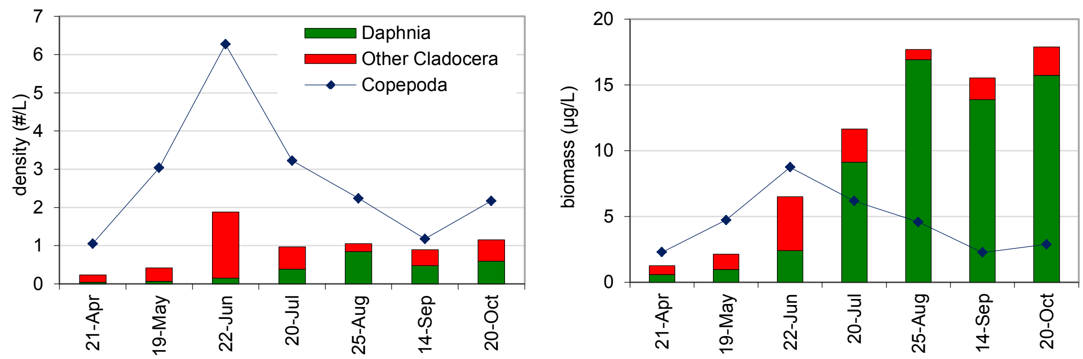


Figure 13. Monthly average zooplankton density (top) and biomass (bottom) in Revelstoke Reservoir in 2015

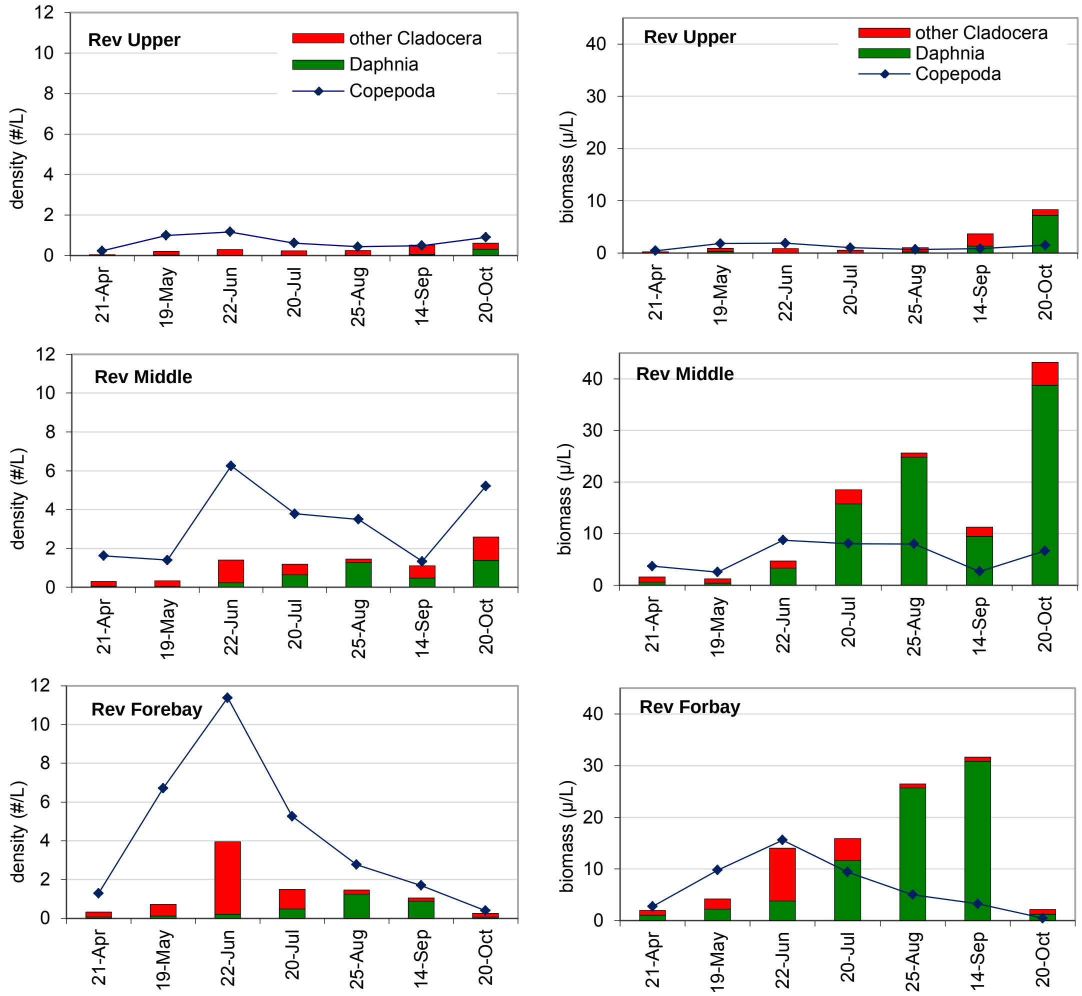


Figure 14. Zooplankton density and biomass at three stations in Revelstoke Reservoir 2015

During 2015 sampling season Copepods were the most numerous in June with 6.27 individuals/L consisting mainly of *D. bicuspidatus thomasi.* They numerically prevailed during the whole sampling season, with the most numerous populations of 11.38 individuals/L found at station Rev Forebay (Fig. 14).

The pattern of seasonal changes of zooplankton density and biomass was similar to the pattern in previous sampling seasons. In each year number of Copepoda increased at the beginning of the summer, reaching its maximum in June-August, and decreasing during the fall. *Daphnia* density increased at the end of summer and trough fall, while number of other Cladocera peaked in June or July (Fig. 13). Other Cladocerans were composed mainly of *Holopedium* and *Bosmina*, averaging 0.12 and 0.45 individuals/L respectively, in the whole reservoir. In June 2015, at station Rev Forebay the number of other cladocerans was the highest in the season due to a peak of *Bosmina* with 2.48 individuals/L and *Holopedium* with 1.26 individuals/L. In terms of biomass, other cladocerans contributed 13% to the total zooplankton biomass. Their biomass was less than 5 µg/L at each station during the whole 2015 sampling season, except in June at Rev Forebay when biomass of other cladocerans was 10.17 µg/L (Fig. 14).

Number of *Daphnia* was low during the entire sampling season in 2015. It was less than 1.50 individual/L at each station. Although *Daphnia* were present in samples during the entire season, they accounted for 0 to 32% of the zooplankton community from April to October. Its density was relatively low averaging 0.04 to 0.85 individual/L at all three stations (Fig. 13). However, *Daphnia* biomass was the highest of three zooplankton groups averaging 8.52 µg/L during the sampling season 2015 (Fig. 12, Tab.7). The highest *Daphnia* biomass was found at Rev Middle station with 38.76 µg/L in October, when *Daphnia* accounted for 78% of the total zooplankton biomass at that time (Fig. 14).

4.3 Seasonal and Along-Lake Patterns

The seasonal development of zooplankton density and biomass in Revelstoke Reservoir follow the usual pattern of increasing copepods in spring and early summer, and a cladoceran increase in the summer and fall (Fig. 13). Copepods dominated numerically during the entire sampling season. Cladocerans were present in significant numbers in June and July, while *Daphnia* spp., although was present in samples during the whole season, made up the majority of the biomass from July to October.

During 2015 peak total zooplankton density occurred in July with 4.20 individuals/L (Tab. 7, Fig. 13). The peak total zooplankton biomass occurred in August with 22.28 µg/L, when *Daphnia* biomass contributed to 76% of the total zooplankton biomass with 16.93 µg/L.

Along the length of Revelstoke Reservoir zooplankton densities as well as biomass tended to be higher in the middle part of the basin and near the dam (Fig. 14).

Table 7. Monthly average density and biomass of zooplankton in Revelstoke Reservoir in 2015. Density is in units of individuals/L, and biomass is in units of µg/L.

Density		21-Apr	19-May	22-Jun	20-Jul	25-Aug	14-Sep	20-Oct
	Copepoda	1.05	3.03	6.27	3.23	2.24	1.17	2.17
	Daphnia	0.04	0.06	0.15	0.38	0.85	0.47	0.59
	Other Cladocera*	0.19	0.36	1.73	0.59	0.21	0.42	0.56
	Total Zooplankton	**1.28**	**3.46**	**8.15**	**4.20**	**3.29**	**2.07**	**3.32**
Biomass		21-Apr	19-May	22-Jun	20-Jul	25-Aug	14-Sep	20-Oct
	Copepoda	2.29	4.73	8.74	6.17	4.57	2.26	2.88
	Daphnia	0.57	0.96	2.39	9.13	16.93	13.90	15.74
	Other Cladocera**	0.70	1.16	4.13	2.53	0.77	1.63	2.16
	Total Zooplankton	**3.55**	**6.85**	**15.25**	**17.83**	**22.28**	**17.79**	**20.78**

*Values do not include *Daphnia* spp. density.
**Values do not include *Daphnia* spp. biomass.

4.4. *Daphnia* Fecundity

Daphnia spp. gravid females were observed in Revelstoke Reservoir throughout the sampling season. The proportion of females that were gravid was variable across the season and along the reservoir. The proportion of gravid females averaged 0.17 in 2015 (Tab. 8). The seasonal average number of eggs per gravid female was 2.13. Across the sampling season the number of eggs per water volume averaged 0.14 eggs/L, and the number of eggs per capita averaged 0.39 eggs/individual over the study period in 2015.

Table 8. Fecundity data for *Daphnia* spp. in Revelstoke Reservoir 2015. Values are seasonal averages, calculated for samples collected between April and October.

	2015
Proportion of gravid females	0.17
# Eggs per gravid Female	2.13
# Eggs per Litre	0.14
# Eggs per Capita	0.39

5. Conclusions

Kinbasket Reservoir is oligotrophic with a moderate zooplankton density. The zooplankton community is diverse and has a relatively stable cladoceran population with a moderate proportion of *Daphnia* spp., considered as a favourable food for kokanee. Density and biomass of *Daphnia* spp. decreased in 2015 in comparison to the previous year. Zooplankton composition is more or less uniform and overall total zooplankton density and biomass, as well as that of copepods, cladocerans, and *Daphnia* do not differ much from station to station.

Revelstoke Reservoir is also oligotrophic with a moderate zooplankton density, and a relatively stable cladoceran population. Density and biomass of *Daphnia* spp. decreased in the 2015 season in comparison to the previous year.

In comparison to historical data it is notable that zooplankton abundance in both reservoirs, Kinbasket and Revelstoke has increased over the time period. These changes have likely been due to combination of climatic changes, predation, nutrients availability, grazeable algae and especially of shifting from riverine (before impoundment) toward lake habitat.

5. References

Brooks, J.L. 1959. Cladocera. pp. 586-656. In Edmondson, W.T. (Ed.) Fresh-Water Biology, 2nd Ed. John Wiley and Sons, New York.

Division of Applied Biology, BC Research, 1977. Limnology of Arrow, McNaughton, Upper Campbell and Williston Lakes. BC Hydro, Project No. 1-05-807.

Fleming, J.O. and H.A. Smith, 1988. Revelstoke Reservoir Aquatic Monitoring Program, 1986 Progress Report. BC Hydro, Report No. ER 88-03.

McCauley, E. 1984. The estimation of the abundance and biomass of zooplankton in samples. In: A Manual on Methods for the Assessment of Secondary Productivity in Fresh Waters.

Downing, J.A. and F.H. Rigler (eds.), Blackwell Scientific Publications, Boston.

Pennak, R.W. 1989. Fresh-Water Invertebrates of the United States: Protozoa to Mollusca. 3rd Ed., John Wiley and Sons, New York, 628 p.

Sandercock, G.A. and Scudder, G.G.E. 1996. Key to the Species of Freshwater Calanoid Copepods of British Columbia. Department of Zoology, UBC Vancouver, BC.

Schindler, E.U., H. Andrusak, K.I. Ashley, G.F. Andrusak, L. Vidmanic, D. Sebastian, G. Scholten, P. Woodruff, J. Stockner, F. Pick, L.M. Ley and P.B. Hamilton. 2007a. Kootenay Lake Fertilization Experiment, Year 14 (North Arm) and Year 2 (South Arm) (2005) Report. Fisheries Project Report No. RD 122, Ministry of Environment, Province of British Columbia.

Schindler, E.U., L. Vidmanic, D. Sebastian, H. Andrusak, G. Scholten, P. Woodruff, J. Stockner, K.I. Ashley and G.F. Andrusak. 2007b. Arrow Lakes Reservoir Fertilization Experiment, Year 6 and 7 (2004 and 2005) Report. Fisheries Project Report No. RD 121, Ministry of Environment, Province of British Columbia.

Watson, T.A. 1985. Revelstoke Project, Water Quality Studies 1978-1984. BC Hydro, Report No. ESS-108.

Wilson, M.S. 1959. Free-living copepoda: Calanoida. pp. 738-794. In Edmondson, W.T. (Ed.) Fresh-Water Biology, 2nd Ed. John Wiley and Sons, New York.

Appendix 8

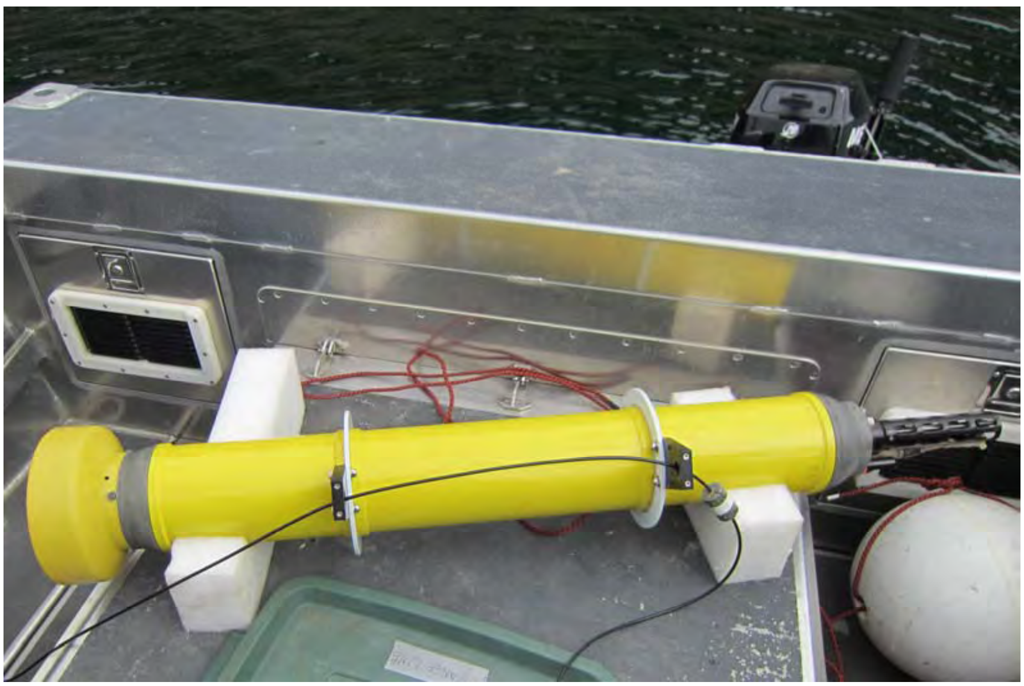
Moorings
Kinbasket and Revelstoke Reservoirs, 2015

Roger Pieters and Greg Lawrence
University of British Columbia

Moorings,
Kinbasket and Revelstoke Reservoirs,
2014 and 2015

Roger Pieters[1,2], and Greg Lawrence[2]

[1] Earth and Ocean Sciences, University of British Columbia, Vancouver, B.C. V6T 1Z4
[2] Civil Engineering, University of British Columbia, Vancouver, B.C. V6T 1Z4



Autonomous profiler (yellow) attached to nylon covered wire (thin black) by sliders (black blocks) and showing the top stopper (grey with white tape) in back of the boat, 01 June 2016

Prepared for

Karen Bray
British Columbia Hydro and Power Authority
1200 Powerhouse Road
Revelstoke B.C. V0E 2S0

December 7, 2016

Contents

List of Figures

1. Introduction

This report provides an update on the collection of data from moored temperature recorders at fixed sites in Kinbasket and Revelstoke Reservoirs for the B.C. Hydro project "CLBMON-56 Addendum #1 to CLBMON-3 Kinbasket and Revelstoke Reservoirs Ecological Productivity Monitoring Program - Mica Project Units 5 and 6 Addendum." The overall plan and goals are briefly summarized, and selected data from the moorings are presented.

The goal of the ongoing CLMBON-3 project has been to collect long-term data describing basic processes needed to understand reservoir limnology, to investigate long-term trends in pelagic conditions, and to improve our understanding of the effect of reservoir operation on ecosystem function. To address the effect of the addition of two turbines to the Mica powerhouse (Mica 5 and Mica 6), the goal of the CLBMON-56 addendum is to collect data from moorings of temperature recorders at fixed locations.

Included in this work is collection of data from two base locations: the forebay of Revelstoke Reservoir, and the forebay of Kinbasket Reservoir. The goal is to collect data from these two base locations throughout the duration of the project. Instruments have also been moored at other locations, such as at the mid and upper sampling stations in Revelstoke Reservoir. These moorings may be moved in subsequent years to examine processes at other locations.

Data from moored temperature recorders will complement data gathered by conductivity-temperature-depth (CTD) surveys for CLBMON-3, conducted on average once a month from May to October (Pieters and Lawrence 2016a). Temperature recorders will provide data with high temporal resolution, observing reservoir behaviour between the monthly CTD surveys.

Data from the moorings will provide information about how rapid changes in inflows and outflows affect a variety of processes such as internal seiches, interflows, and transport of water into the photic zone. These processes are important, for example, to the replenishment of nutrients needed for pelagic productivity in the photic zone (Pieters and Lawrence 2012). Work for CLBMON-56 will include measurement of wind and other meteorological data at the surface of the reservoir. Wind and cooling can drive mixing of the surface layer, as well as internal seiches and upwelling, which are all linked to understanding pelagic productivity.

2. Methods

During the summer of 2012, a trial of four different types of moorings was undertaken in the forebay of Revelstoke Reservoir. These four types have subsequently been used for moorings at other locations. The types of moorings are given in Table 2.1 and illustrated in Figure 2.1; the location of moorings is provided in Table 2.2.

Table 2.1 Type of moorings

Name	Description
SUB	Subsurface mooring
BOOM	Line from log boom near dam
SPAR	Spar mooring
PROF	Autonomous profiler

Table 2.2 Location of moorings

Name	UTM Easting(11U)/Northing	Latitude/ Longitude
Rev FB SUB	416,926E 5,657,518N	51° 3.790 N 118° 11.132 W
Rev FB BOOM	416,468E 5,656,304N	51° 3.131 N 118° 11.507 W
Rev FB PROF	417,057E 5,657,845N	51° 3.968 N 118° 11.024 W
Rev FB SPAR	416,846E 5,657,294N	51° 3.668 N 118° 11.197 W
Rev LAF* PROF	413,627E 5,677,983N	51° 14.799 N 118° 14.250 W
Rev LAF* SPAR	413,857E 5,677,722N	51° 14.662 N 118° 14.049 W
Rev MID SUB	398,452E 5,699,022N	51° 25.997 N 118° 27.652 W
Rev UP SUB	385,521E 5,731,847N	51° 43.550 N 118° 39.451 W
Kin FB SUB	393,754E 5,772,744N	52° 5.702N 118° 33.058 W
Kin FB BOOM	392,223E 5,771,051N	52° 4.772 N 118° 34.368 W
Kin MID SPAR	400,307E 5,775,586N	52° 7.309 N 118° 27.371 W

* Near La Forme Creek, ~18 km north of Revelstoke Dam, and 30 km south of Rev MID at Downie.

From October 2012 to August 2016, forty additional moorings were successfully deployed and recovered in a variety of locations. The location, type and duration of moorings are summarized in Table 2.3.

Table 2.3 Moorings, 2012 to 2016

N	RES	LOC	TYPE	START	END
201	REV	FB	SUB	16-Aug-2012	11-Oct-2012
202	REV	FB	TB*	18-Jul-2012	11-Oct-2012
203	REV	FB	SPAR	16-Aug-2012	11-Oct-2012
204	REV	FB	PROF	11-Sep-2012	11-Oct-2012
205	REV	FB	SUB	11-Oct-2012	26-Aug-2013
206	REV	FB	BOOM	11-Oct-2012	26-Aug-2013
207	REV	MID	SUB	12-Sep-2012	26-Aug-2013
208	REV	UP	SUB	12-Sep-2012	26-Aug-2013
209	KIN	FB	SUB	13-Sep-2012	30-Aug-2013
210	KIN	FB	BOOM	13-Sep-2012	30-Aug-2013
211	REV	FB	SPAR	25-Apr-2013	20-May-2014
212	REV	FB	PROF	25-Apr-2013	20-May-2014
213	REV	MID	SPAR	26-Apr-2013	20-May-2014
214	REV	MID	PROF	26-Apr-2013	20-May-2014
215	REV	FB	SUB	28-Aug-2013	22-Aug-2014
216	REV	FB	BOOM	28-Aug-2013	22-Aug-2014
217	REV	MID	SUB	29-Aug-2013	22-Aug-2014
218	REV	UP	SUB	29-Aug-2013	22-Aug-2014
219	REV	UP	PROF	29-Aug-2013	22-Aug-2014
220	KIN	FB	SUB	30-Aug-2013	29-Aug-2014
221	KIN	FB	BOOM	30-Aug-2013	29-Aug-2014
222	REV	FB	PROF	23-May-2014	22-Aug-2014
223	REV	MID	SPAR	11-Jul-2014	22-Aug-2014
224	REV	MID	PROF	11-Jul-2014	22-Aug-2014
225	REV	FB	SUB	27-Aug-2014	28-Aug-2015
226	REV	FB	BOOM	27-Aug-2014	28-Aug-2015
227	REV	FB	PROF	27-Aug-2014	28-May-2015
228	REV	MID	SUB	28-Aug-2014	28-Aug-2015
229	REV	MID	PROF	28-Aug-2014	28-May-2015
230	REV	UP	SUB	28-Aug-2014	28-Aug-2015
231	KIN	FB	SUB	29-Aug-2014	02-Sep-2015
232	KIN	FB	BOOM	29-Aug-2014	11-Dec-2014
233	KIN	FB	BOOM2	25-May-2015	02-Sep-2015
234	REV	MID	PROF	02-Jun-2015	26-May-2016
235	REV	FB	PROF	03-Jun-2015	26-May-2016
236	REV	LAF	PROF	03-Jun-2015	26-May-2016
237	REV	LAF	SPAR	03-Jun-2015	26-May-2016
238	REV	FB	SUB	01-Sep-2015	19-Aug-2016
239	REV	FB	BOOM	01-Sep-2015	19-Aug-2016
240	REV	MID	SUB	01-Sep-2015	19-Aug-2016
241	REV	UP	SUB	01-Sep-2015	19-Aug-2016
242	KIN	FB	SUB	02-Sep-2015	24-Aug-2016
243	KIN	FB	BOOM	02-Sep-2015	24-Aug-2016
244	KIN	MID	SPAR	01-Jun-2016	24-Aug-2016

* Trial line of Onset TidBits at Revelstoke Dam boom, see Pieters and Lawrence (2016b).

Temperature recorders consisted of Onset Hobo Water Temp Pro V2 (HWTP) recorders, Seabird SBE56 recorders and RBR SoloT recorders. The characteristics of the temperature recorders are given in Table 2.4. Because of their low cost, HWTP recorders were typically used every 2 m while the more accurate, but more expensive SBE56 or SoloT recorders were used every 20 m.

Table 2.4 Temperature recorders

Instrument	Resolution	Accuracy	Time response	Typical annual sample rate	Max depth
HWTP	0.02°C	±0.2 °C	5 min	15 min	120 m
SBE56	0.0001°C	±0.002 °C	0.5 sec	10 sec	1500 m
RBR SoloT	0.00005 °C	±0.002 °C	~1 sec	5 sec	1700 m
RBR Duo	0.00005 °C	±0.002 °C	~1 sec	5 sec	200 m*

* Limited by the pressure sensor

To assess movement of the moorings, pressure (depth) recorders were also used. These were either RBR Duo TD recorders which measure both temperature and pressure, or RBR SoloD recorders.

The SUB, SPAR and BOOM moorings used 5/8 inch Samson Quick Splice single-braid bi-polymer olefin line (specific gravity 0.94, weight 7.0 kg/100 m, average strength 3000 kg). The line was chosen to be buoyant, have good handling, low abrasion and little stretch.

All except the BOOM moorings use an Interocean Model 111 acoustic release, which is located just above the anchor. Upon receiving a coded acoustic signal, the release disconnects from the anchor, and the float carries the mooring and release to the surface (or frees the spar). This allows for recovery of the mooring without the anchor, and makes it possible to recover the moorings from a smaller boat without the need for a crane. The extended-life battery option enables deployments for up to one year.

A schematic of the four types of moorings is shown in Figure 2.1 for Revelstoke Forebay, and are described as follows. Moorings at other locations were similar in design.

REV FB BOOM The short line attached to the log boom near the dam is meant to record temperature in the near surface which is not sampled by Rev FB SUB (below). This line rises and falls with water level. A steel weight of approximately 35 lbs (16 kg) was attached at the bottom of the line to keep it vertical.

REV FB SUB This is a subsurface mooring; the float is below the water surface. In Revelstoke there is little water level variation so the float can be located a few meters below the surface, and depending on water clarity, the float can be seen from the boat. The float consists of two 14 inch (36 cm) diameter hard shell trawl floats which together provide approximately 80 lbs (36 kg) of floatation at the top of the mooring, balanced by 160 lbs (72 kg) of steel anchor at the bottom. As the mooring line is anchored at the bottom, it does not rise and fall with changes in water level, but remains at a fixed elevation. Use of a subsurface float means the mooring is much less likely to be snagged by surface debris or moved by ice. Instruments are concentrated in the upper part of the mooring, both above and below the level of the intake (~ 30 m depth), see Figure 2.1.

REV FB SPAR The spar buoy consists of an 8 ft (2.4 m) aluminum pole holding three close-cell foam floats with a combined floatation of ~120 lbs (54 kg). The spar is held upright by 5.5 m of ¼ inch chain weighing ~11 lbs (5 kg) attached directly to the spar, and by a weight of 25 lbs (11 kg) at 34 m.

REV FB PROF In addition to traditional temperature recorders, an experimental tethered autonomous profiler was also moored in Revelstoke forebay. The profiler consisted of a Teledyne Webb Apex APF9I float. These type of floats are normally deployed in the open ocean where they reside at depth (e.g. 1000 m), and rise on a regular basis (e.g. every 10 days) to collect a profile of temperature, conductivity and other parameters; upon reaching the surface, the data and GPS location of the float is telemetered by ARGO satellite. There are thousands of these floats throughout the oceans collecting data that would otherwise be very costly to gather by boat.[1] Most of these ocean profilers are treated as expendable, lasting about three years.

We were able to purchase three Apex floats through the NSERC Research Tools and Instruments program. The three floats were specifically designed to slide up and down on a low friction tether consisting of nylon coated stainless steel wire held taut by 80 lbs (36 kg) of subsurface floatation at the top and 160 lbs (72 kg) of anchor at the bottom. This makes these profilers suitable for mooring in lakes and reservoirs. Since the float does not rise all the way to the surface, it does not have satellite communications, and instead data is recorded within the float. The float is capable of collecting daily CTD profiles for more than one year. Once recovered, the data is uploaded, and the batteries are changed for the next deployment. These floats each have a Seabird SBE 41cp CTD and a Seapoint turbidity meter.

[1] See http://www.argo.ucsd.edu/About_Argo.html

3. Temperature Moorings

In this section, data from the temperature moorings are shown as both line and contour plots. In the line plots, the temperature is plotted on the y-axis, and the temperature at each depth is plotted in a different color (color gives depth). In the contour plots the depth is plotted on the y-axis, and each temperature is given a different color (color gives temperature). All data is shown in days of 2008, the first year of the CLBMON-3 program.

3.1 Temperature Moorings in Revelstoke Reservoir

REV FB SUB (Figure 3.1.1 and 3.1.2) Data from 2012 to 2016, are shown as both a line plot (Figure 3.1.1) and a contour plot (Figure 3.1.2). There were short (< 1 week) gaps in the data at the end of August during which time the mooring was serviced. There was also a gap of about one month in the data in September 2015 due to an acoustic release that malfunctioned and opened shortly after deployment. The mooring was found floating on the surface, recovered and redeployed. Temperature recorders were at nominal depths (relative to full pool) of 4.4 to 125 m.

The line plot shows that the near surface (4.4 m) temperature briefly reaches just over 20 °C in July or August of most years (Figure 3.1.1). The temperature near the bottom (125 m) varied around the temperature of maximum density (4 °C), rising slowly to just over 5 °C during the summer, and cooling below 4 °C in winter. What is evident is that there was significantly more cooling in the winter of 2013-2014 than in the other winters on record. This may have resulted from colder weather or windier conditions.

The mooring shows the seasonal temperature cycle as follows:

- The warm surface layer cools and deepens beginning in late August.
- Fall turnover begins December and the entire water column cools from ~6 °C to a minimum of 1 to 3 °C in March.
- Spring turnover begins in March as the entire reservoir warms from winter minimum up to 4.0 °C by April.
- Persistent summer temperature stratification occurs after April.
- The summer stratification is modulated by internal waves at a variety of time scales (see examples in Pieters and Lawrence 2016b).
- During summer, the temperature at the bottom (125 m) is comparatively steady, rising very slowly by ~0.2 °C/month, which is similar to that observed in other deep lakes.

The contour plot (Figure 3.1.2) shows the warm (>15 °C) surface layer is limited to the top 10 to 20 m during the summer. At the same time, there is a layer of water around 8 °C that extends from the 10 m to the about 50 m; this indicates the interflow.

REV FB BOOM (Figures 3.2.1 and 3.2.2) A line was hung from the log boom just upstream of Revelstoke Dam as part of the base mooring in Revelstoke Forebay, collecting data from the top 10 m of the water column. For the most part the temperature was relatively uniform in the top 10 m, though there were periods when there was some stratification within the top 10 m during summer. The coldest temperature at 1 m was about 1 °C in March 2014.

REV MID SUB (Figures 3.3.1 and 3.3.2) This mooring was deployed at the Rev MID sampling station near Downie Arm. At this location, about halfway up Revelstoke Reservoir, turnover occurred from late October to November each year, earlier than at the Rev FB station, but this may simply reflect that the Rev MID station is shallower. In addition, fall and spring turnover at the Rev MID mooring showed more periods of temporary stratification than at Rev FB, including slightly longer and cooler periods of reverse stratification. Summer temperature stratification began at Rev MID after the reservoir reached ~4 °C in April in most years.

REV UP SUB (Figure 3.4.1 and 3.4.2) This mooring was deployed near the Rev UP sampling station. This station is not only shallower but more riverine, showing less temperature stratification than at the MID and FB sites, as can be seen by comparing the contour plots. Reduced stratification was particularly noticeable during high flows in summer 2015 (Figure 3.4.1).

At the start of the mooring in 2012 there was little temperature stratification, and fall turnover began on 4 October 2012 (day 1739, Figure 3.4.1). During fall turnover, the temperature showed fewer periods of secondary stratification than at the MID and FB moorings. However, unlike the MID and FB moorings, the temperature at the UP mooring did not cool monotonically but included periods of 5 to 10 days when the entire water column warmed, possibly due to the influence of upstream inflow. During spring turnover, the shallower water column warmed faster than at the MID and FB moorings, and, in some years, summer stratification began sooner, in late March and early April.

3.2 Temperature Moorings in Kinbasket Reservoir

KIN FB SUB (Figures 3.5.1 and 3.5.2) Because of the large water level variations in Kinbasket Reservoir, the top of the Kin FB SUB mooring had to be kept deeper, just below the minimum water level (40 m below full pool). To provide data from the upper water column at high water level, the Kin FB BOOM mooring was longer, extending to 40 m depth.

Data from 40 to 180 m depth are shown in Figures 3.5.1 and 3.5.2. In summer, the temperature at 40 m reaches 10 to 13 °C (Figure 3.5.1). In fall, the temperature at shallower depths cools (Figure 3.5.1) as the surface layer deepens (Figure 3.5.2) until, in January of each year, the entire water column is close to the temperature of maximum density, 4 °C.

From February to April, reverse stratification is observed. As shallower water cools below the temperature of maximum density, 4 °C, it becomes less dense, and this colder buoyant water caps the warmer water near 4 °C. More reverse stratification was observed in the 2013-2014 winter, suggesting either the winter was colder and/or windier. Note that in the winter of 2012-2013, the entire water column cooled slightly (0.2 °C) below 4 °C.

In Kinbasket forebay, there was no distinct period of either fall or spring turnover (Figure 3.5.1), in contrast to Revelstoke Reservoir (Figures 3.1.1, 3.3.1, and 3.4.1). For example, the surface layer mixed to 80 m depth by 22 December 2013 (day 1818), and this surface layer reached 4 °C around 15 January 2013 (day 1842). However, the 0 to 80 m layer then cooled below 4 °C to develop reverse stratification, without seeming to mix with water below 100 m depth.

One possibility is that a small salinity stratification may have affected turnover. There was a slight salinity stratification observed in some CTD profiles. For example, on 23 April 2013 the conductivity increased from ~150 µS/cm at 100 m to 180 µS/cm at the bottom (Figure B1c in Pieters and Lawrence 2014). Pressure effects may also play a role below ~150 m. Also, complete spring turnover did not occur; rather, the top 80 m warmed through 4 °C leaving the deep temperature below 4 °C (e.g. 3.6 °C in spring 2013). The deep water warmed gradually (~0.05 °C/mo) through the summer, suggesting a small degree of exchange with water above 100 m, like observed Revelstoke Reservoir. Note, that the deep water remained well oxygenated (e.g. Figure B1e in Pieters and Lawrence 2016a).

KIN FB BOOM (Figures 3.6.1 and 3.6.2) Unfortunately, in 2012-2013 the instruments on the boom mooring below 2 m were lost (likely due to a shackle that was not closed tightly). In 2013-2014 the mooring appeared to have rubbed against a line holding the log boom in place, and instruments below 16 m were lost. In December 2014 the boom broke, and the boom and instrument line were found on shore; the top two instruments were broken but the rest were undamaged and the mooring was redeployed in May 2015. Available data are plotted in Figures 3.6.1 and 3.6.2, and show a seasonal cycle similar to that in Revelstoke Reservoir.

4. Profilers

From 2012 to 2016, three profilers were deployed at various locations in Revelstoke Reservoir (Table 2.3). In this report, all available profiler data has been plotted over the same time period for a given year, May to November, the stratified productive season. The time, depth, temperature, salinity, and turbidity scales have been kept the same in all figures to facilitate comparison between locations and years. The only exception is the salinity scale for Rev UP in 2014, in which the lower bound of the salinity scale was set to 25 rather than 30 mg/L to accommodate fresh water observed during the spring (Figure 4.5c).

To understand the patterns observed in the profiler data, consider briefly the summer circulation of Revelstoke Reservoir. The flow and conductivity in Revelstoke Reservoir can be roughly divided into two periods (Pieters and Lawrence, 2016a). In the first period, during spring and early summer, inflow from Kinbasket Reservoir is relatively low, and inflow to Revelstoke Reservoir is dominated by relatively fresh snowmelt from local tributaries. This typically results in the development of relatively low salinity which extends throughout the top 60 m of the reservoir by mid-July.

In mid-July, a big change occurs in most years with a sudden increase of deep outflow from Kinbasket Reservoir, from less than 100 m^3/s to greater than 1000 m^3/s. This outflow is cool and slightly more saline, and forms an interflow along the length of the reservoir centered on the outlet of 30 m depth at Revelstoke Dam. This interflow is typically inserted into the less saline spring melt water, and remnants of the low salinity water can, in some years, be observed both near the surface and around 60 m depth all the way into October (e.g. Figure 4.1b). After October, fall cooling and deepening of the surface layer act to mix the interflow and the remnants of the spring inflow water.

Revelstoke FB Profiler, Sep-Oct 2012 (Figure 4.1) The first profiler was deployed as a trial for one month from 11 September to 11 October 2012, sampling every 4.9 hours, and collecting a total of 146 profiles. Temperature, raw salinity and turbidity data are shown as contour plots in Figure 4.1. This data is plotted on a large time scale for comparison with subsequent data. The profiler data was shown on expanded scale in the previous report (Figure 3.5, Pieters and Lawrence, 2016a).

Revelstoke UP Profiler, Aug – Nov 2013 (Figure 4.2) In 2013-2014, the three profilers were deployed at the Rev FB, MID and UP stations. While the profilers were successfully recovered, data was accidently erased from the Rev FB and Rev MID profilers (the self-test command erases memory). The data from the Rev UP profiler is shown here for the 2013 productive season. There is not only little stratification in temperature (as observed in the temperature moorings, Figures 3.4.1 and 3.4.2), but little stratification in salinity and turbidity as well.

Revelstoke FB Profiler, May – Nov, 2014 (Figure 4.3) This is the first plot showing the evolution of temperature, salinity and turbidity over the whole productivity season. The emergence of thermal stratification is seen beginning in late May (Figure 4.3a). At the same time, a deepening fresher layer is evident in salinity (Figure 4.3b, late May to mid-August).

From mid-August to mid-October the interflow is evident as a layer of slightly increased salinity centered on 30 m (Figure 4.3b). The interflow is modulated by internal motions with a period of 5 to 15 days, which can bring the interflow into the photic zone, and even bring the interflow to the surface. After mid-October, the interflow was mixed to the surface by fall cooling. By mid-November, the surface layer extended to the bottom of the interflow, 60-70 m depth. Turbidity shows occasional pulses, as well as an increase near the bottom in the fall (Figure 4.3c).

Revelstoke MID Profiler, May – Nov, 2014 (Figure 4.4) The profiler at Rev MID shows a similar seasonal pattern as that at Rev FB, except that the interflow appears a little sooner, in early August (Figure 4.4c). White bars mark occasions when the profiler failed to rise to the surface.

Revelstoke UP Profiler, May – Nov, 2014 (Figure 4.5) There were many occasions when the profiler failed to rise to the surface, especially toward the end of the record. As observed in the previous fall, there was little stratification in temperature, salinity, or turbidity at Rev UP (Figure 4.5). However, the presence of slightly more saline (and less turbid) water from Kinbasket Reservoir can be seen in late July, first below 20 m and then throughout the water column.

Revelstoke FB, LAF and MID Profilers, May – Nov, 2015 (Figure 4.6 - 4.8)

In May 2015, the profiler that had previously been at the Rev UP station was deployed near La Forme Creek (station Rev LAF), which is located about 18 km upstream of the Rev FB station, but downstream of the Rev MID station. The purpose was to understand the variation in internal motions between the Rev FB and Rev MID stations.

Note that, after 21 September 2015 (day 261), the Rev LAF profiler no longer rose to the surface. This coincided with an extraordinary rain event on 20 September 2015. Elevated tributary turbidity was observed to originate from high elevations which lacked snow cover. This storm may have contributed to the heavy layer of fine material found on the profiler when it was recovered, and this material may have prevented the profiler from rising.

In 2015, the flow from Kinbasket Reservoir did not drop as much in the spring, remaining much higher through the summer. As a result, the interflow appeared earlier in the year: it was observed at the Rev MID station by the end of June 2015 (Figure 4.8b), at Rev LAF by early July 2015 (Figure 4.7b), and at Rev FB by mid-July 2015 (Figure 4.6b).

Acknowledgements

We thank B. Manson, P. Bourget and K. Bray for their assistance in the field. We thank E. Pieters, A. Sharp, K. Lywe, C. Huang, M. Mewhort, A. Quainoo and T. Rodgers for assistance with instrument setup and upload, and the UBC Work-Learn and NSERC Undergraduate Summer Research Awards programs for salary subsidy. We gratefully acknowledge funding provided by B.C. Hydro. We acknowledge the NSERC Research Tools and Instruments program for funding the purchase of the profilers.

References

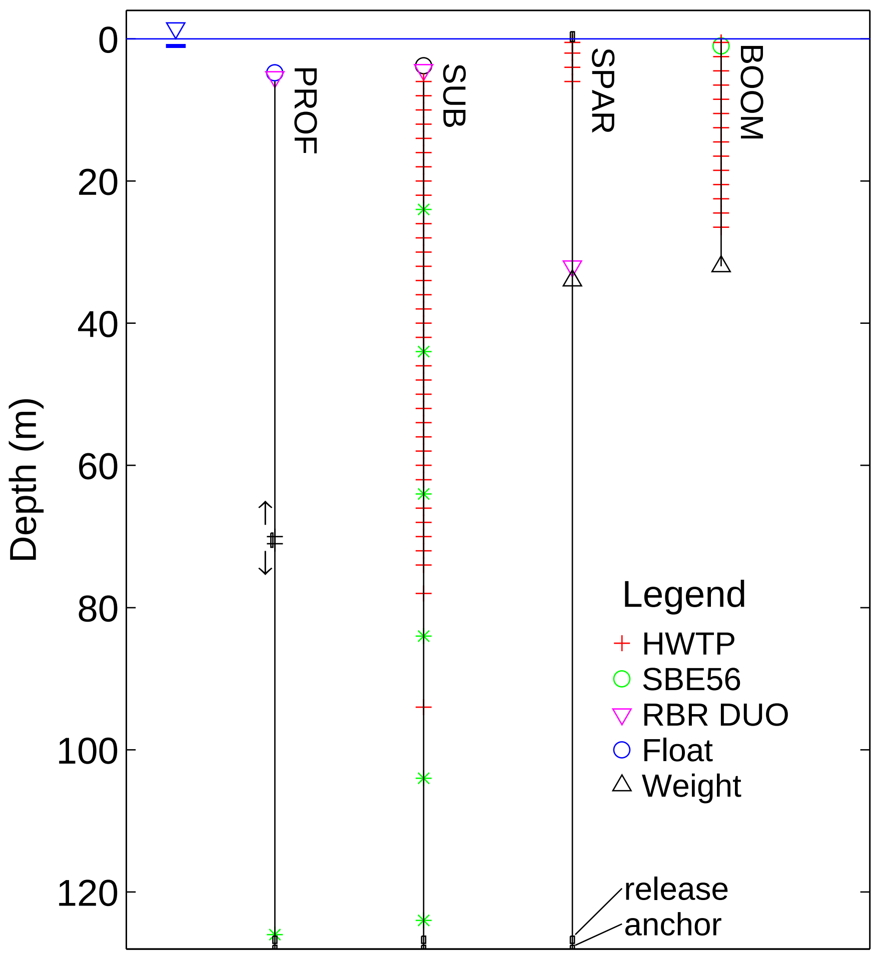
Pieters, R. and G. Lawrence. 2012. Plunging inflows and the summer photic zone. Water Quality Research Journal of Canada. 47.3-4, 268-275. Doi: 10.2166/wqrjc.2012.143

Pieters, R., and G. Lawrence. 2014. CTD Surveys, Kinbasket and Revelstoke Reservoirs, 2012. 56 pp. Appendix 3 in Bray K. 2014. Kinbasket and Revelstoke Reservoirs Ecological Productivity Monitoring. Progress Report Year 5 (2012). BC Hydro, Environment. Study No. CLBMON-3.

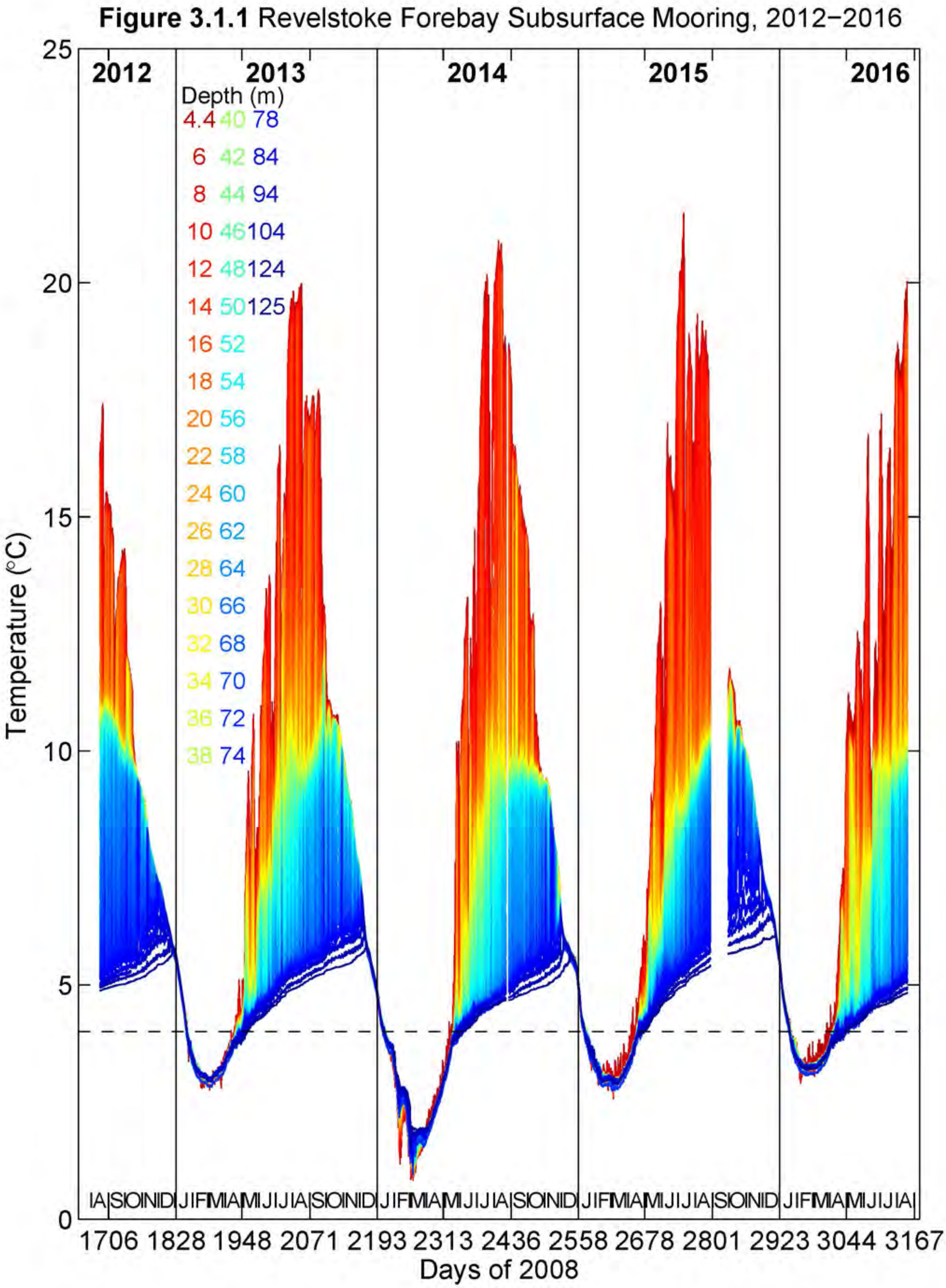
Pieters, R., and G. Lawrence. 2016a. CTD Surveys, Kinbasket and Revelstoke Reservoirs, 2013. 64 pp. Appendix 3 in Bray K. 2016. Kinbasket and Revelstoke Reservoirs Ecological Productivity Monitoring. Progress Report Year 6 (2013). BC Hydro, Environment. Study No. CLBMON-3.

Pieters, R., and G. Lawrence. 2016b. Moorings, Kinbasket and Revelstoke Reservoirs, 2013. 64 pp. Appendix 8 in Bray K. 2016. Kinbasket and Revelstoke Reservoirs Ecological Productivity Monitoring. Progress Report Year 6 (2013). BC Hydro, Environment. Study No. CLBMON-3 and CLBMON-56.

Figure 2.1 Revelstoke Forebay Moorings, 2012

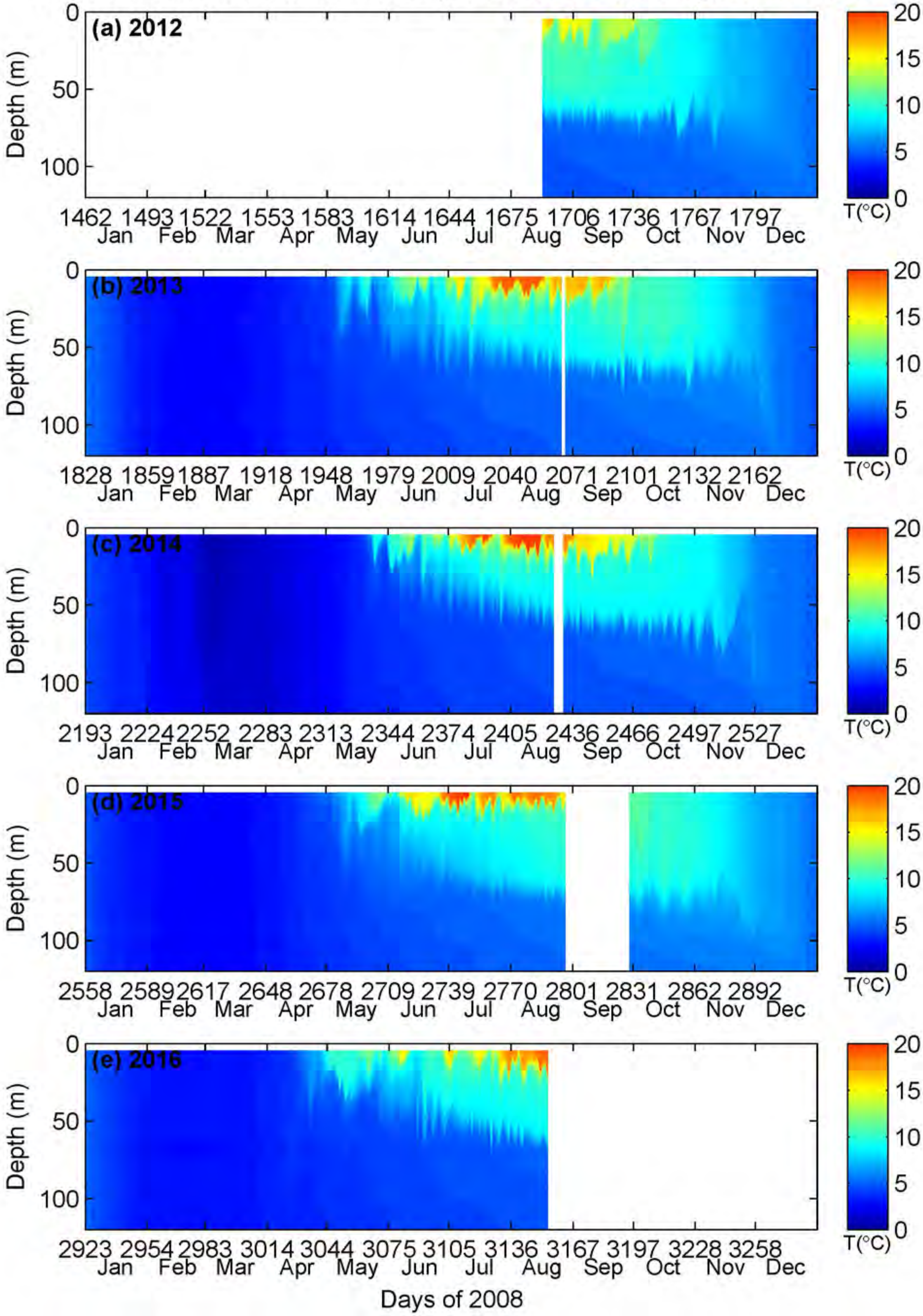


/ocean/rpieters/kr/moor/schem/moorschemRevFB2012.m fig= 1 2014−Oct−01



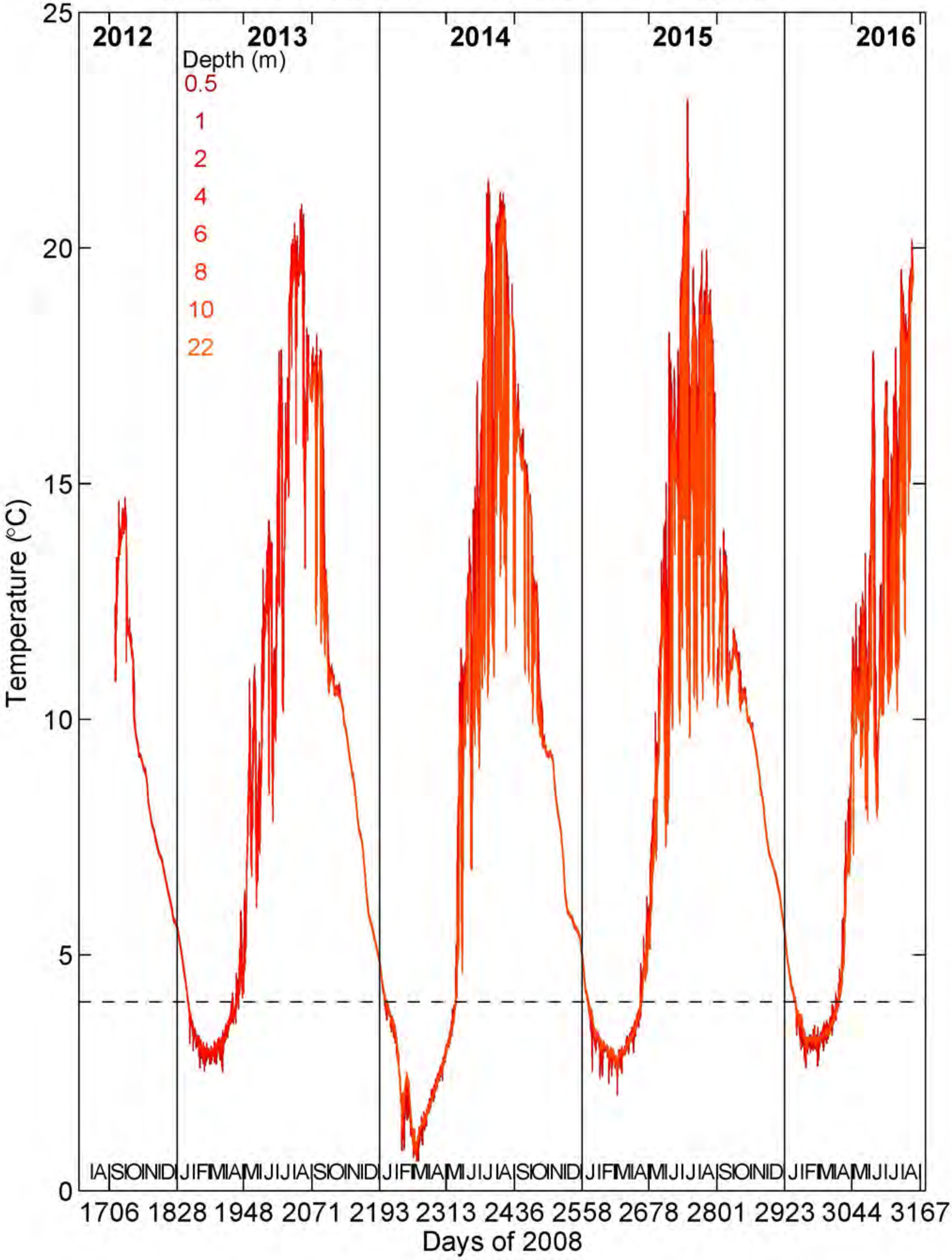
/ocean/rpieters/kr/moor/plot16/plotlineall.m fig= 1 2016−Nov−30

Figure 3.1.2 Revelstoke Forebay Subsurface Mooring, 2012−2016



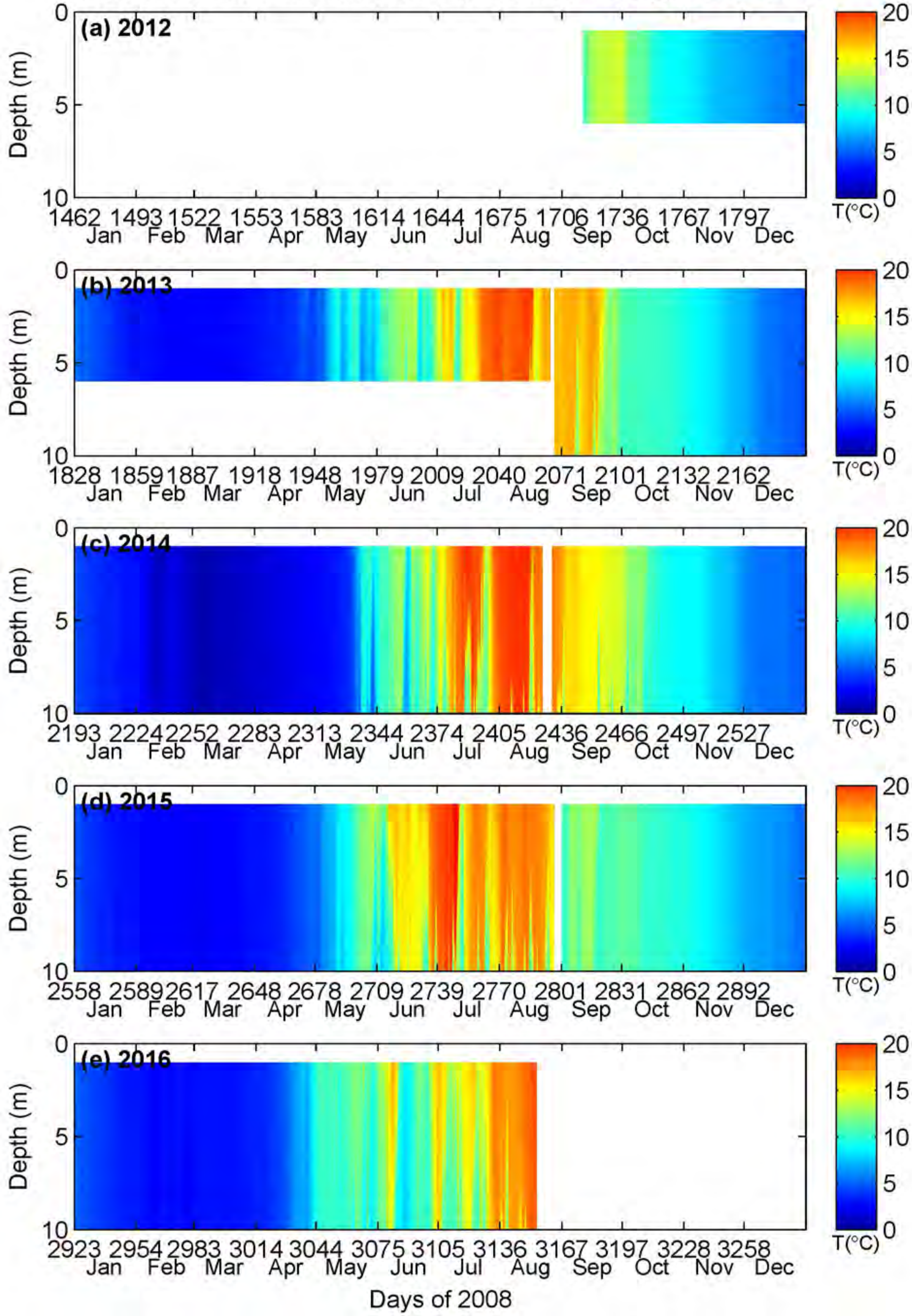
/ocean/rpieters/kr/moor/plot16/plotcontyrall.m fig= 1 2016−Dec−01

Figure 3.2.1 Revelstoke Forebay Boom Mooring, 2012−2016



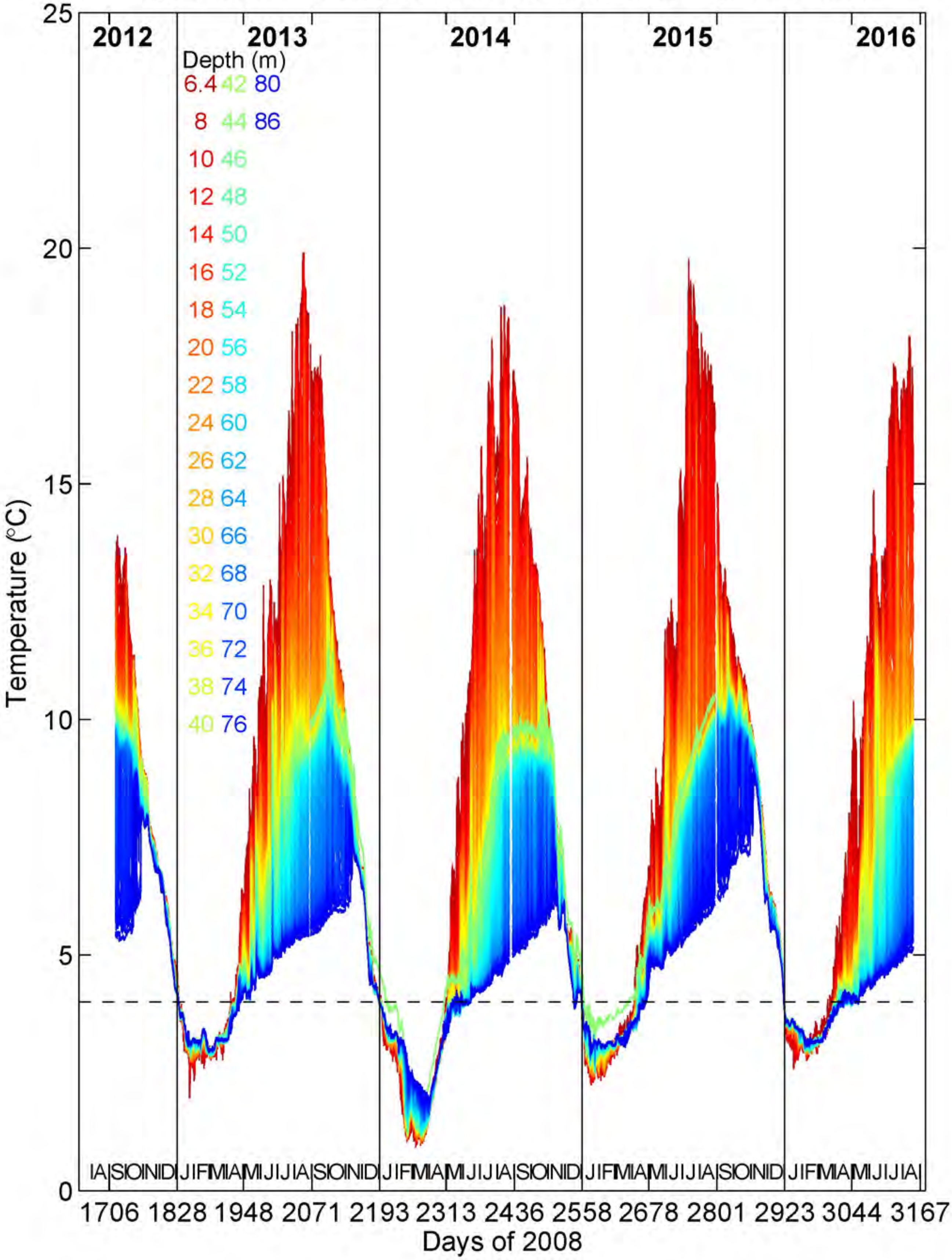
/ocean/rpieters/kr/moor/plot16/plotlineall.m fig= 2 2016−Nov−30

Figure 3.2.2 Revelstoke Forebay Boom Mooring, 2012−2016



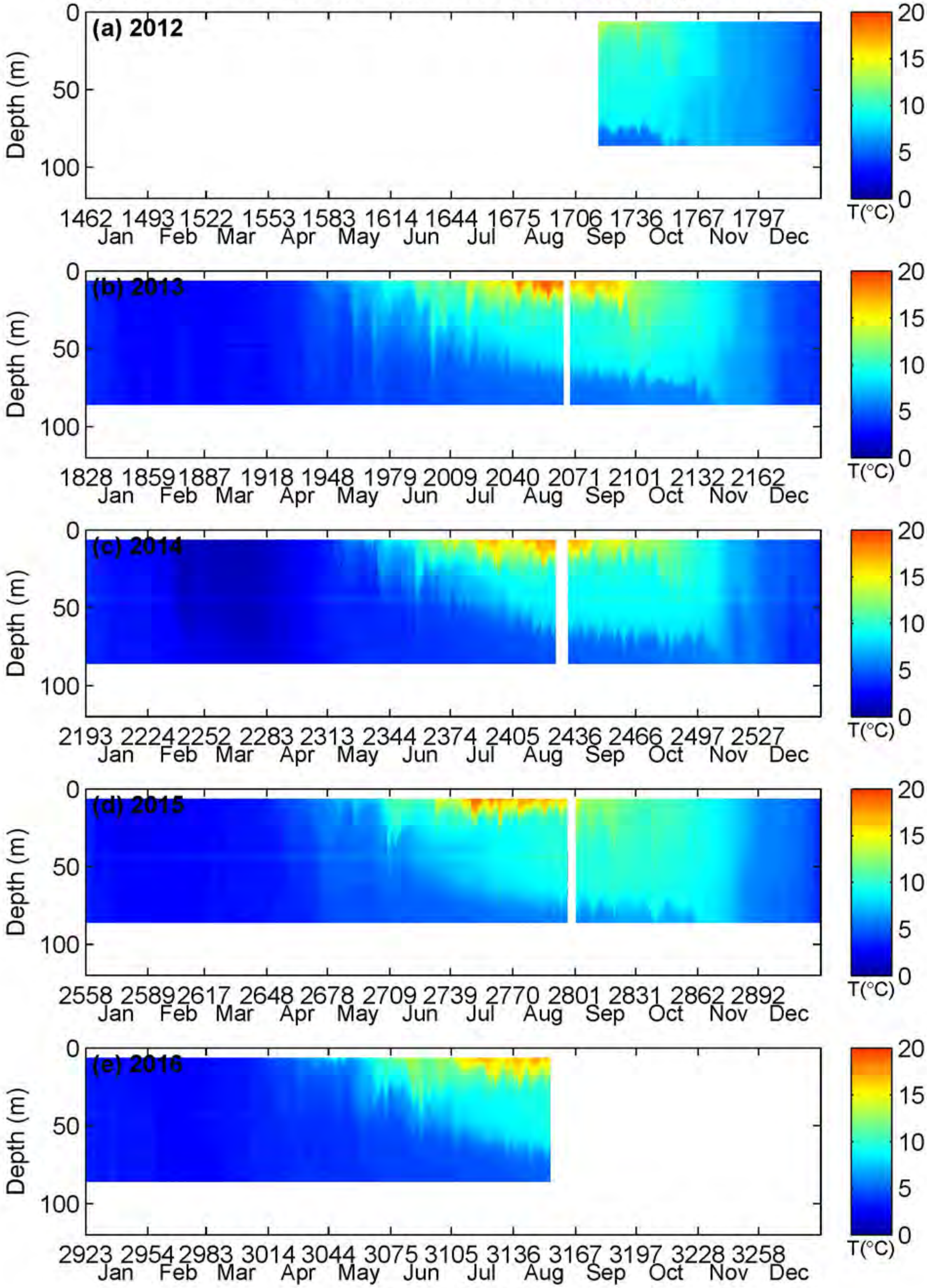
/ocean/rpieters/kr/moor/plot16/plotcontyrall.m fig= 2 2016−Dec−01

Figure 3.3.1 Revelstoke Mid Subsurface Mooring, 2012−2016



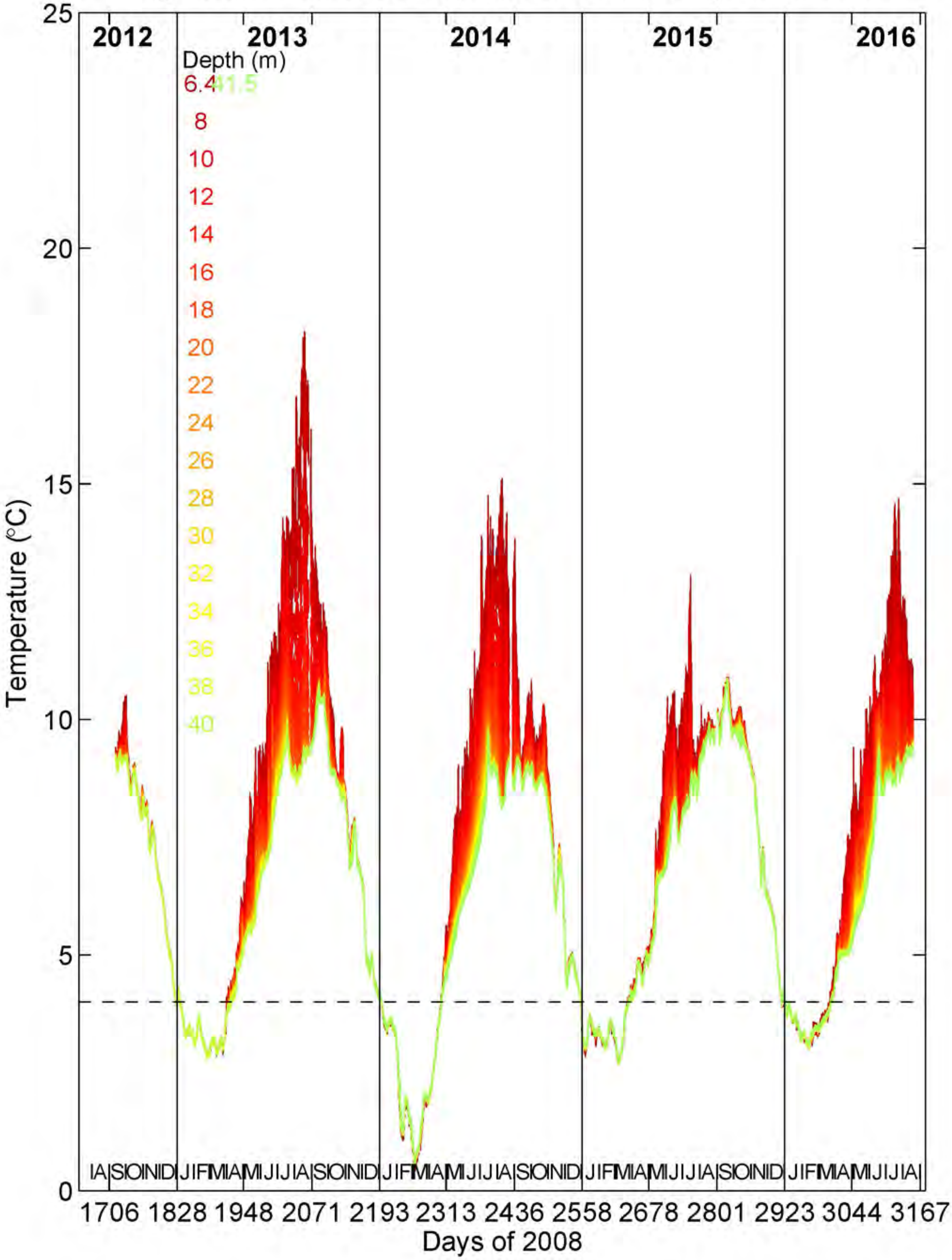
/ocean/rpieters/kr/moor/plot16/plotlineall.m fig= 3 2016−Nov−30

Figure 3.3.2 Revelstoke Mid Subsurface Mooring, 2012−2016



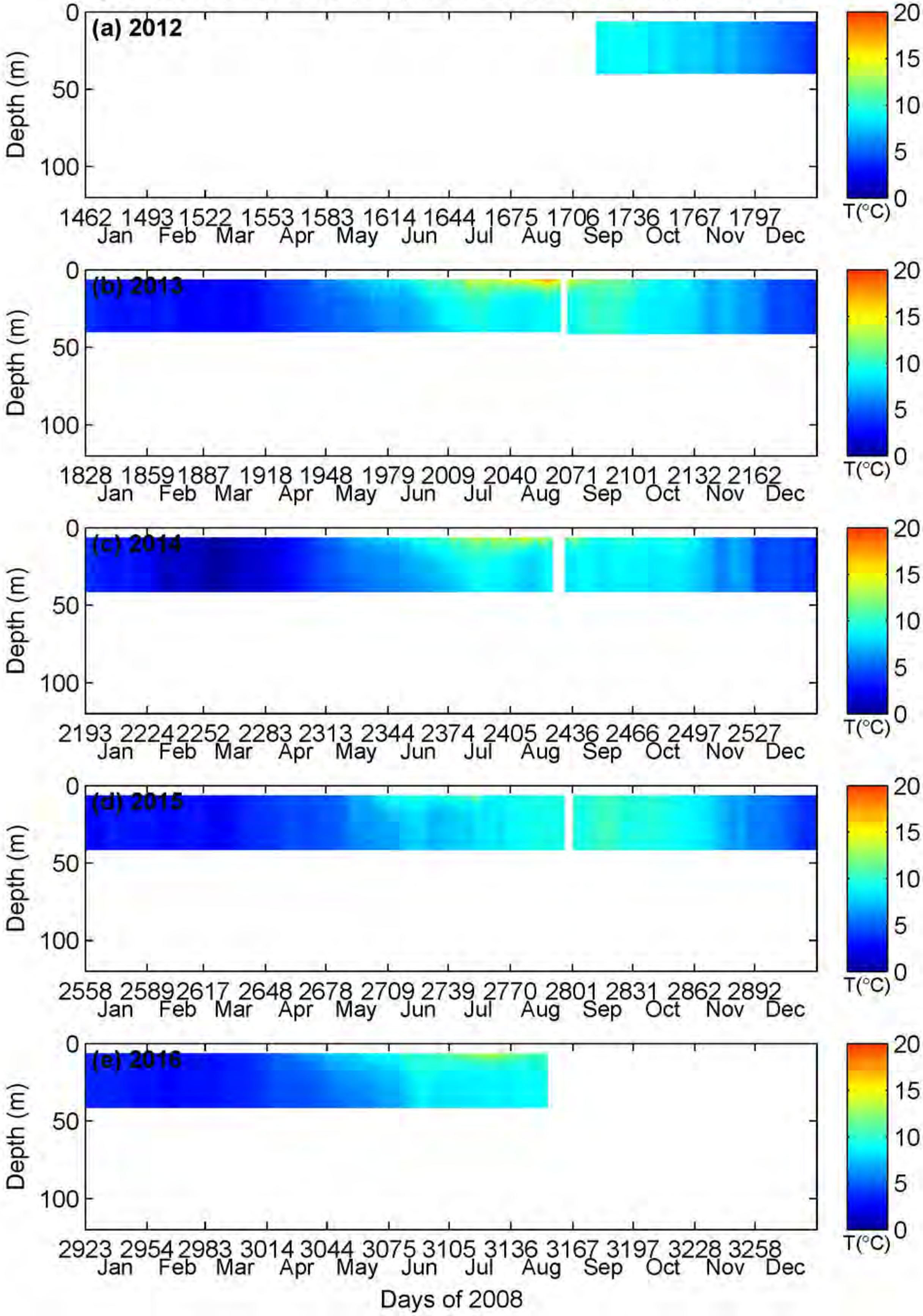
/ocean/rpieters/kr/moor/plot16/plotcontyrall.m fig= 3 2016−Dec−01

Figure 3.4.1 Revelstoke Up Subsurface Mooring, 2012−2016



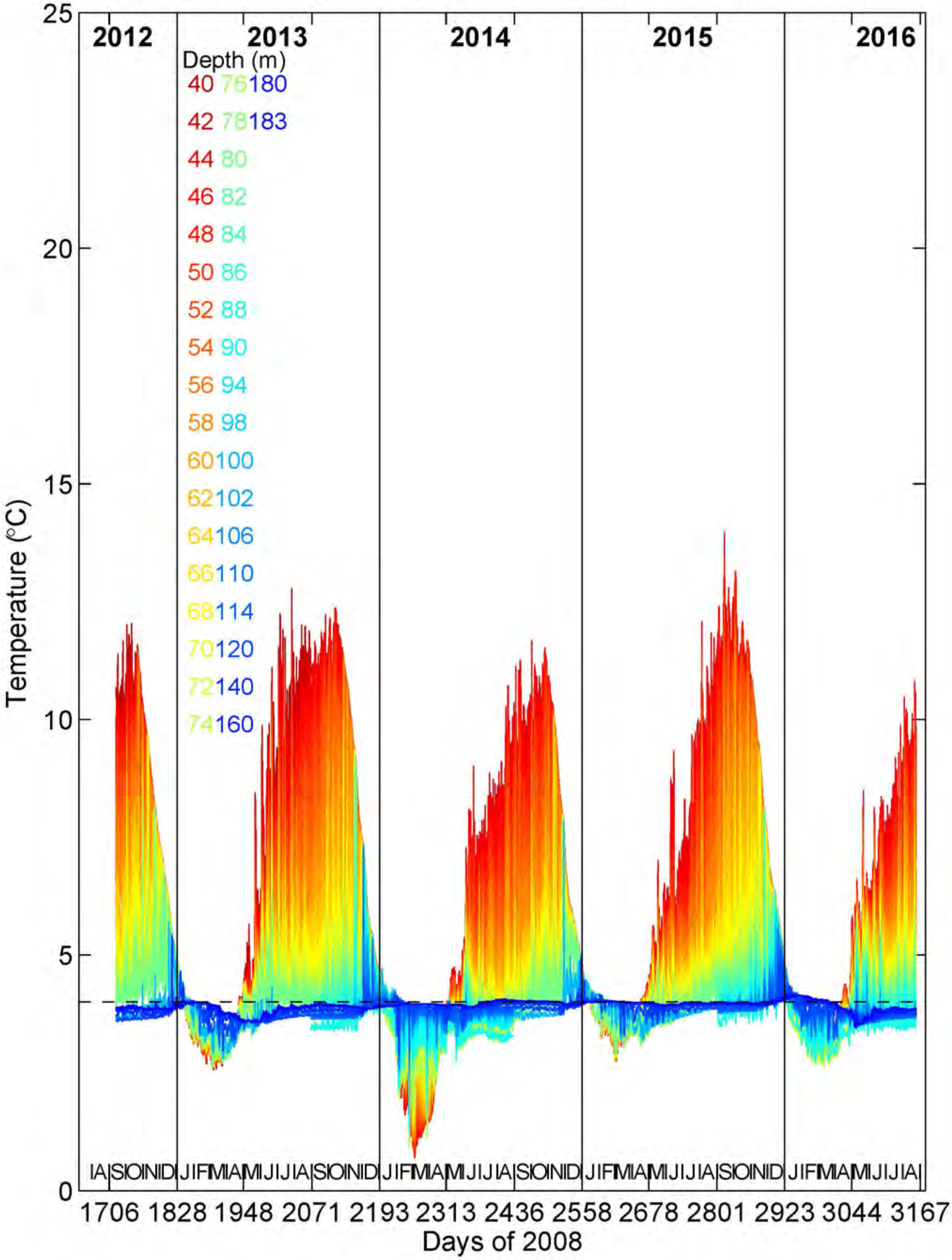
/ocean/rpieters/kr/moor/plot16/plotlineall.m fig= 4 2016−Nov−30

Figure 3.4.2 Revelstoke Up Subsurface Mooring, 2012−2016



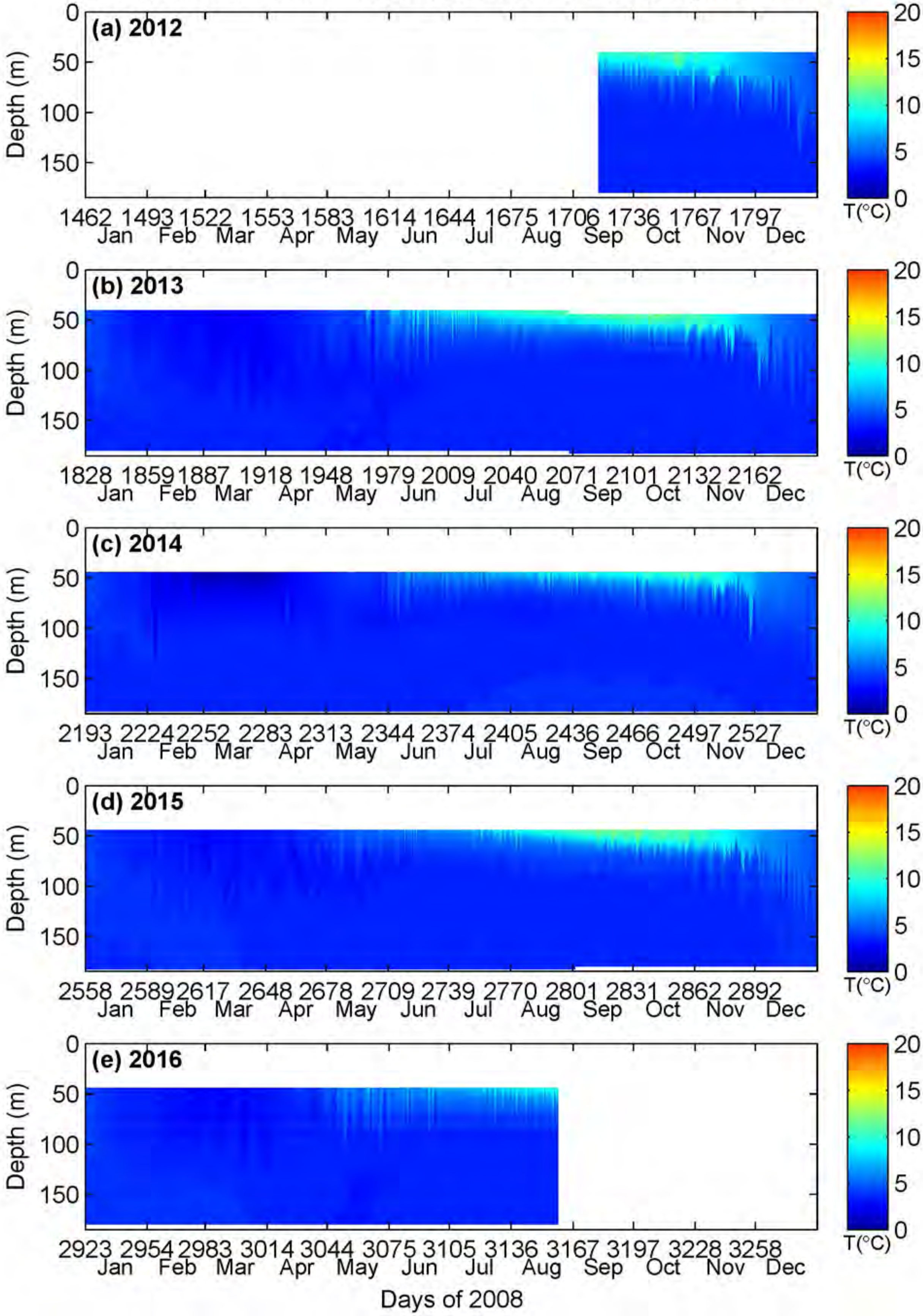
/ocean/rpieters/kr/moor/plot16/plotcontyrall.m fig= 4 2016−Dec−01

Figure 3.5.1 Kinbasket Forebay Subsurface Mooring, 2012−2016



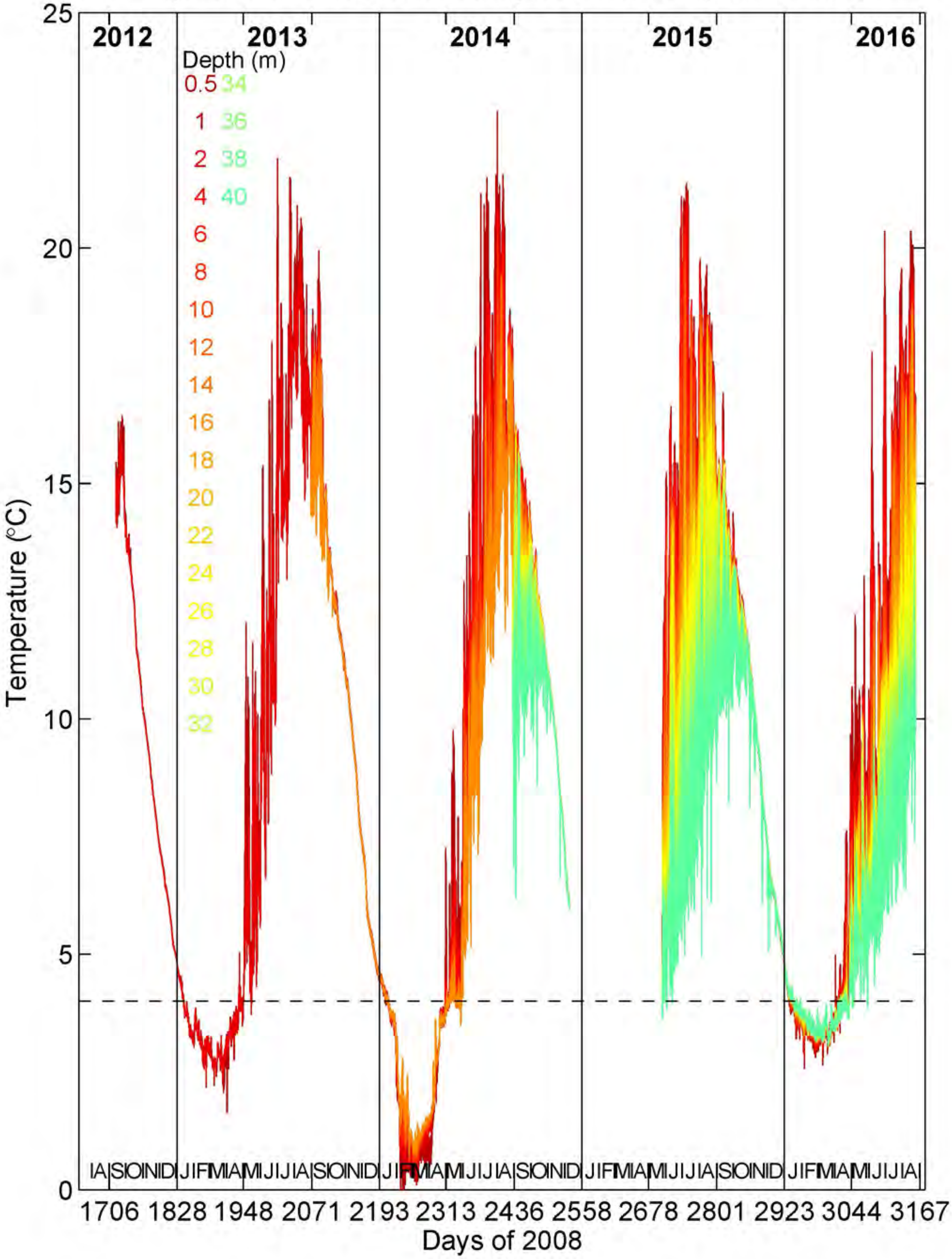
/ocean/rpieters/kr/moor/plot16/plotlineall.m fig= 5 2016−Nov−30

Figure 3.5.2 Kinbasket Forebay Subsurface Mooring, 2012−2016



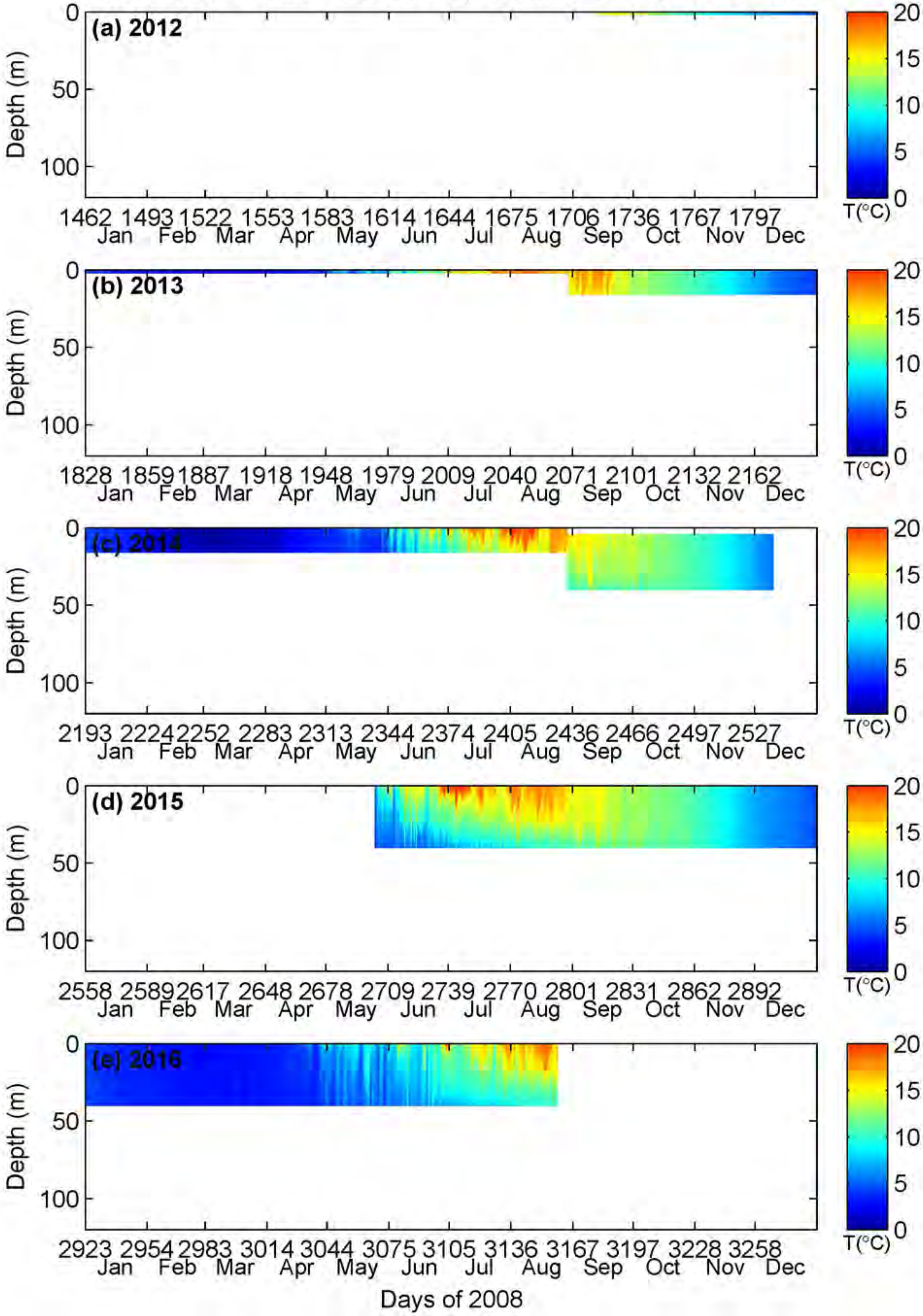
/ocean/rpieters/kr/moor/plot16/plotcontyrall.m fig= 5 2016−Dec−01

Figure 3.6.1 Kinbasket Forebay Boom Mooring, 2012−2016



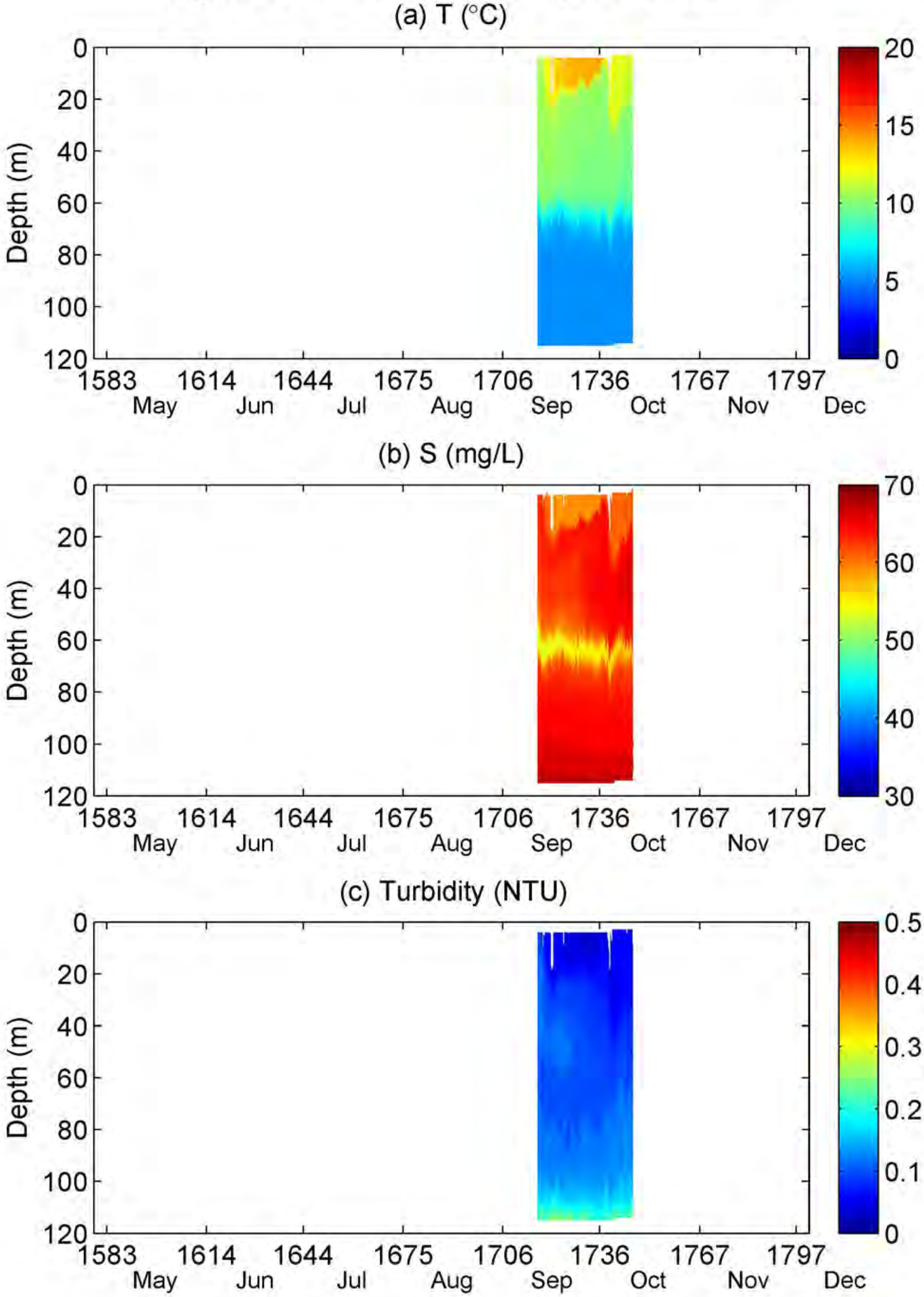
/ocean/rpieters/kr/moor/plot16/plotlineall.m fig= 6 2016−Nov−30

Figure 3.6.2 Kinbasket Forebay Boom Mooring, 2012−2016



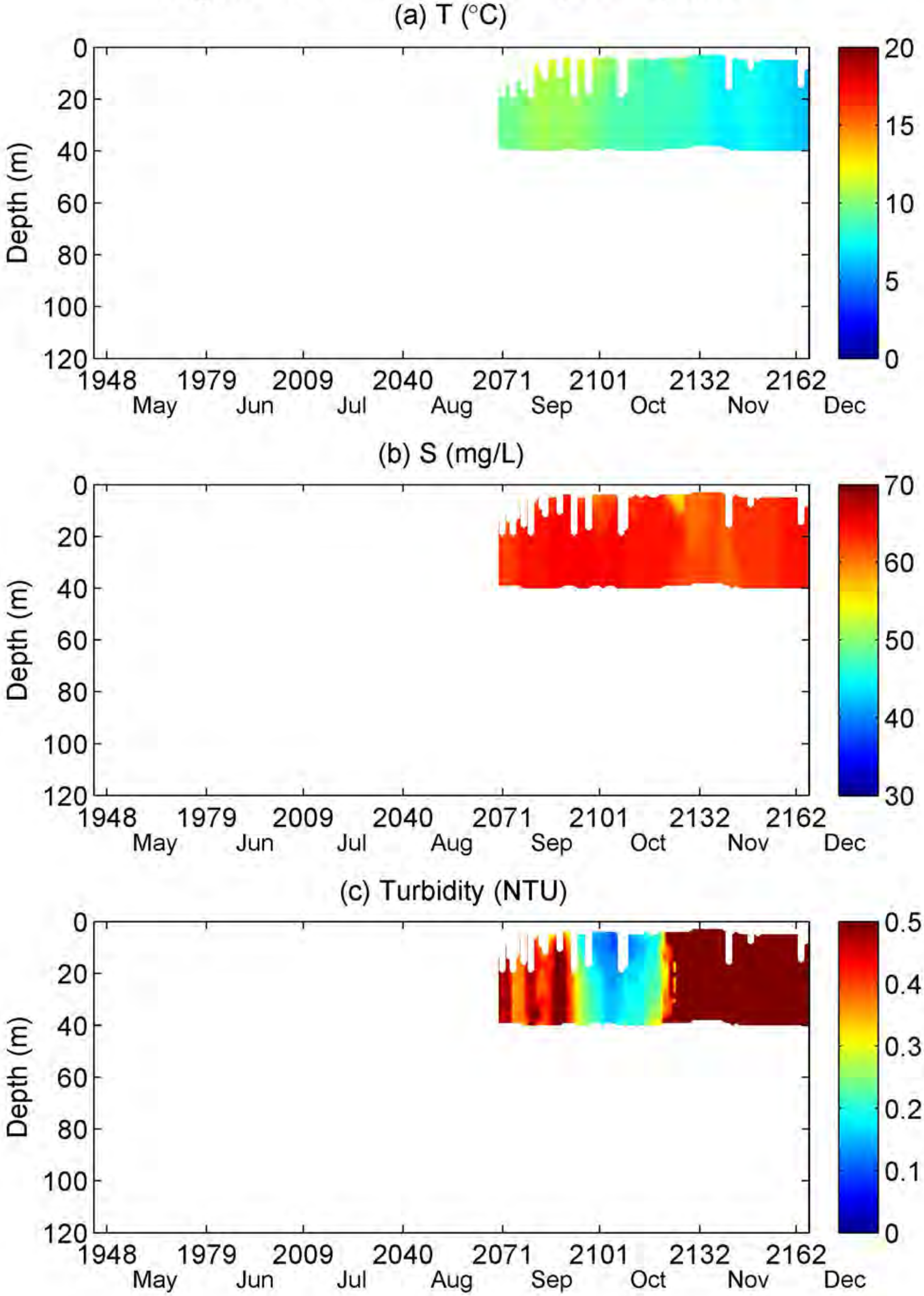
/ocean/rpieters/kr/moor/plot16/plotcontyrall.m fig= 6 2016−Dec−01

Figure 4.1 Rev FB Profiler, May to Nov, 2012



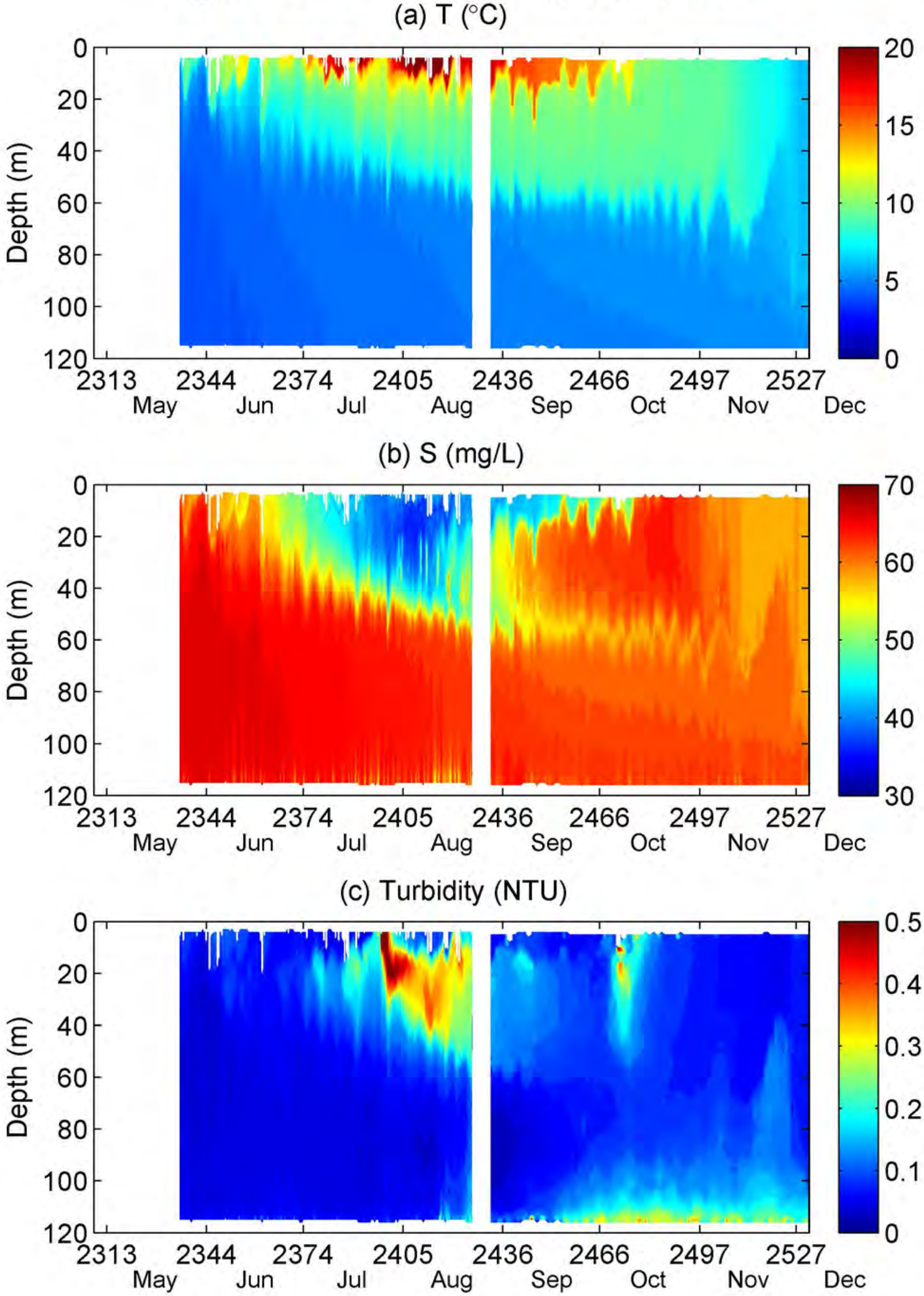
/ocean/rpieters/kr/prof/plot16/profcontcombo2.m fig= 6 2016−Nov−30

Figure 4.2 Rev Up Profiler, May to Nov, 2013



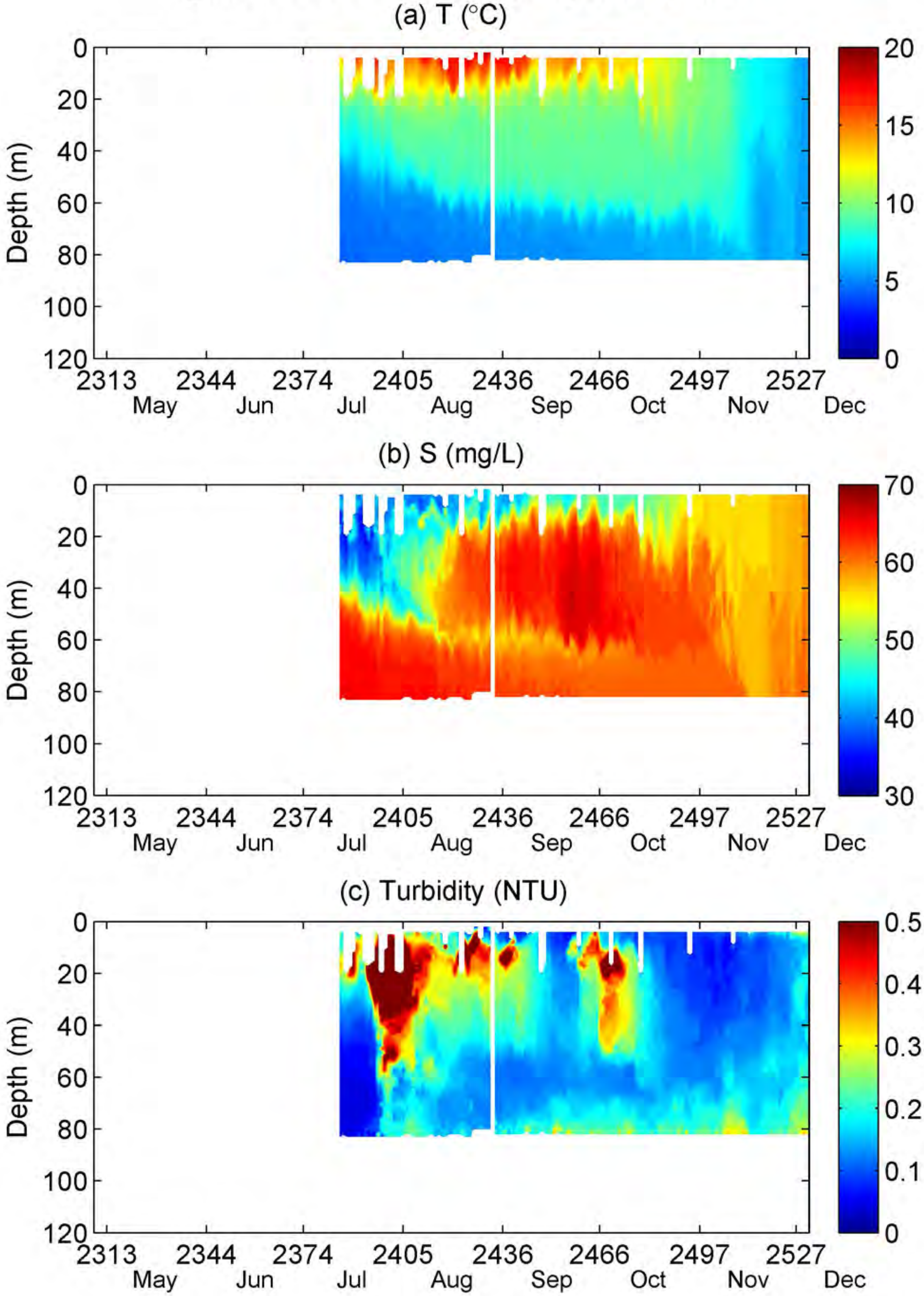
/ocean/rpieters/kr/prof/plot16/profcontcombo2.m fig= 7 2016−Nov−30

Figure 4.3 Rev FB Profiler, May to Nov, 2014



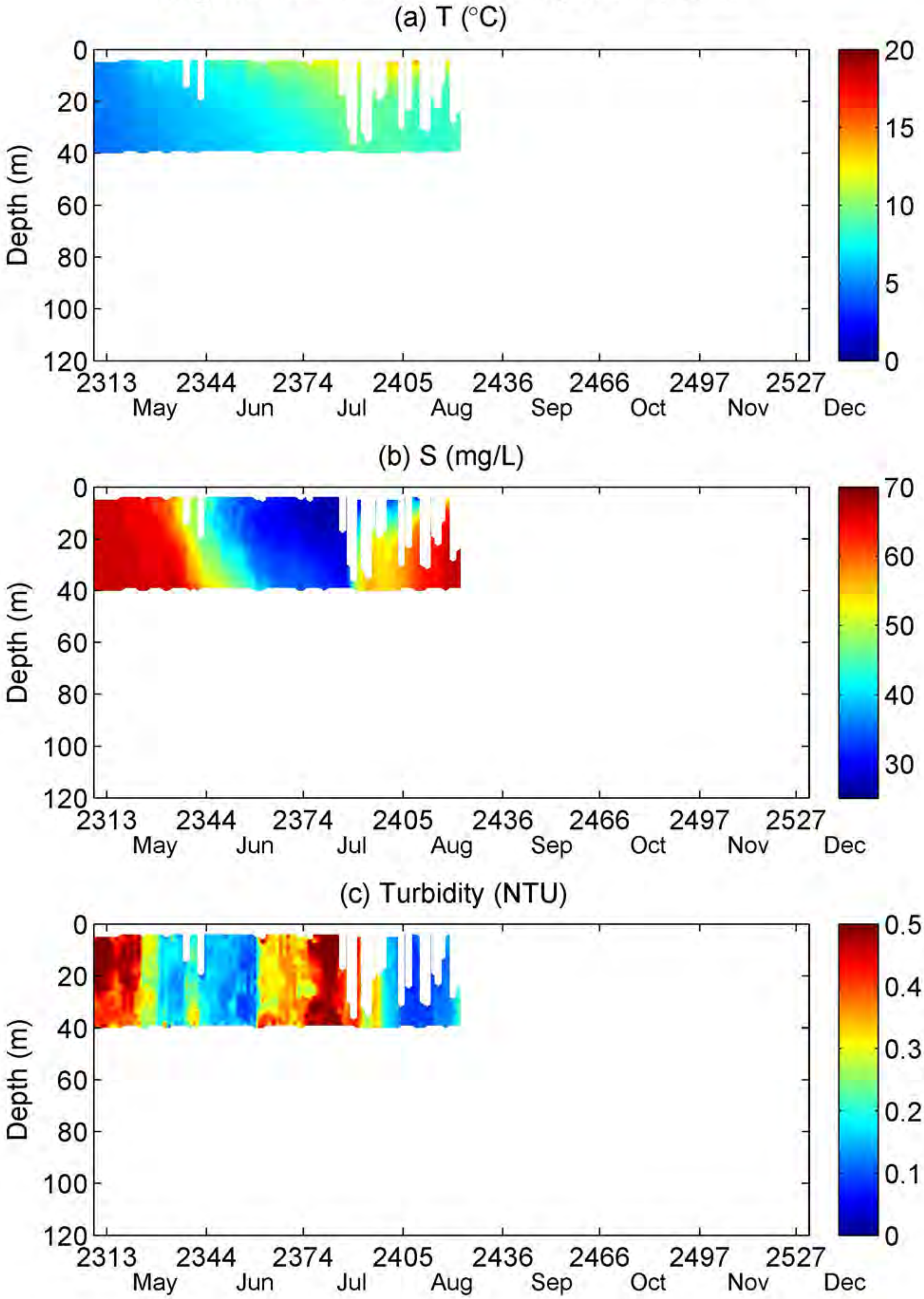
/ocean/rpieters/kr/prof/plot16/profcontcombo2.m fig= 1 2016−Nov−30

Figure 4.4 Rev MID Profiler, May to Nov, 2014



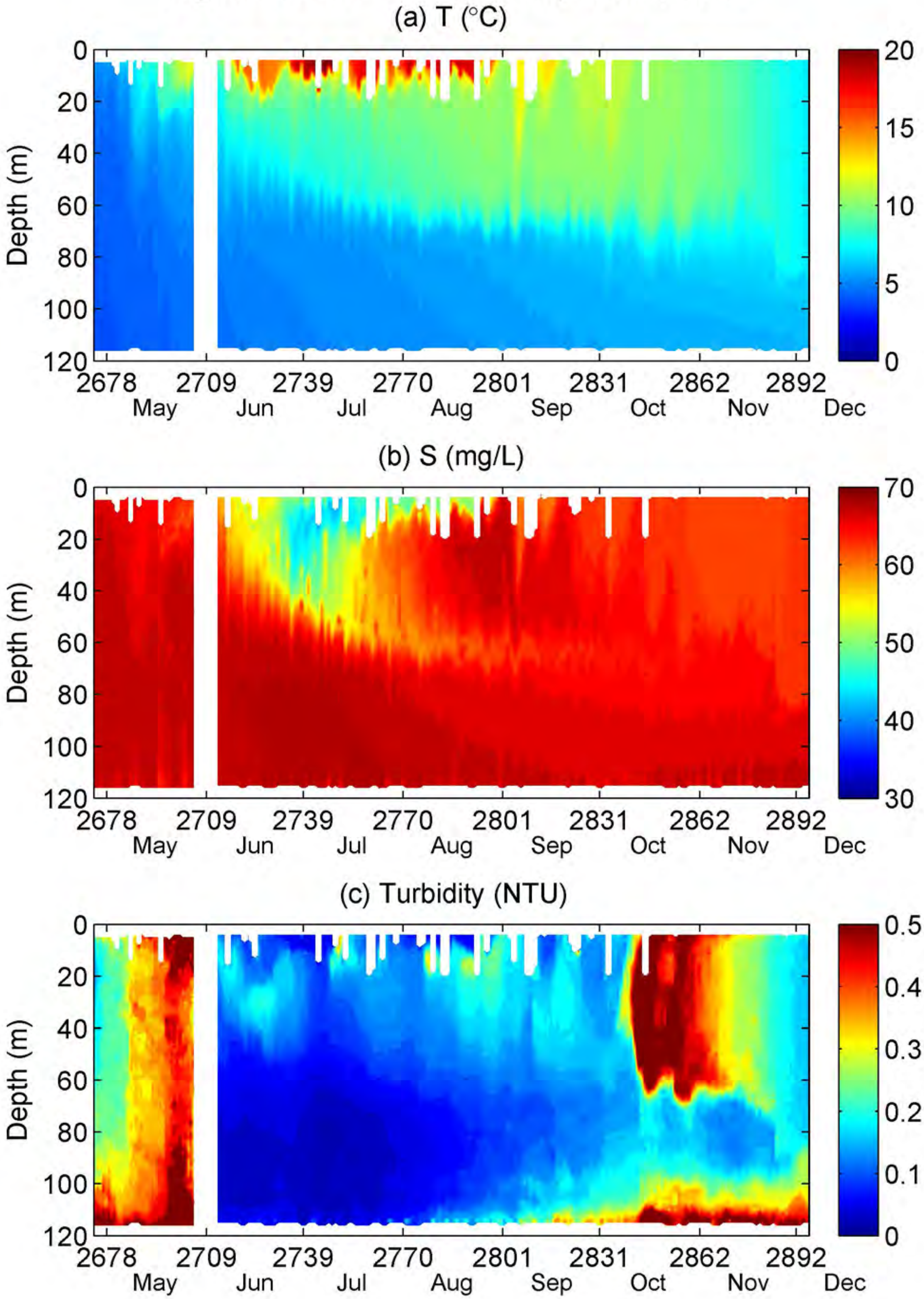
/ocean/rpieters/kr/prof/plot16/profcontcombo2.m fig= 2 2016−Nov−30

Figure 4.5 Rev Up Profiler, May to Nov, 2014



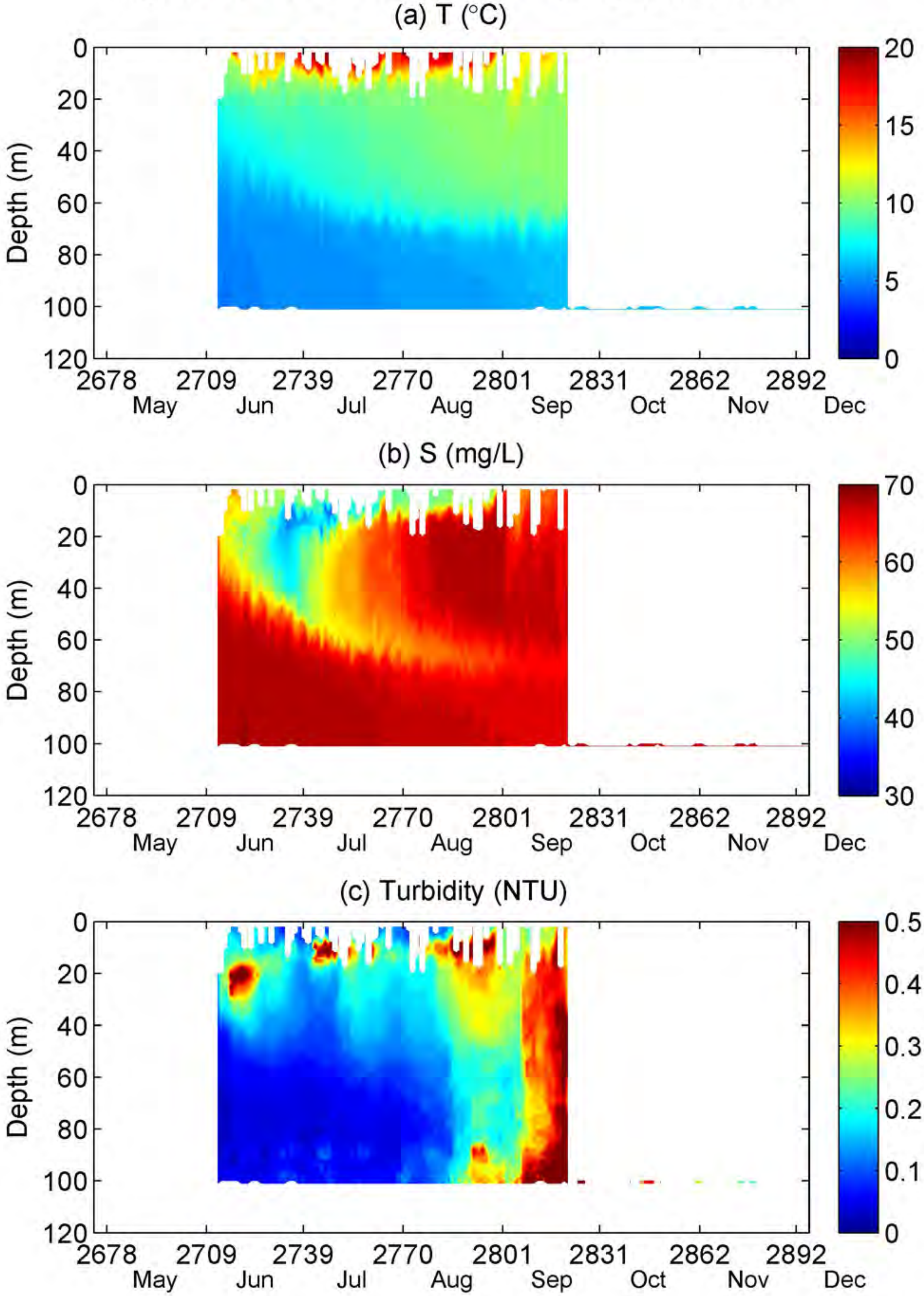
/ocean/rpieters/kr/prof/plot16/profcontcombo2.m fig= 8 2016−Nov−30

Figure 4.6 Rev FB Profiler, May to Nov, 2015



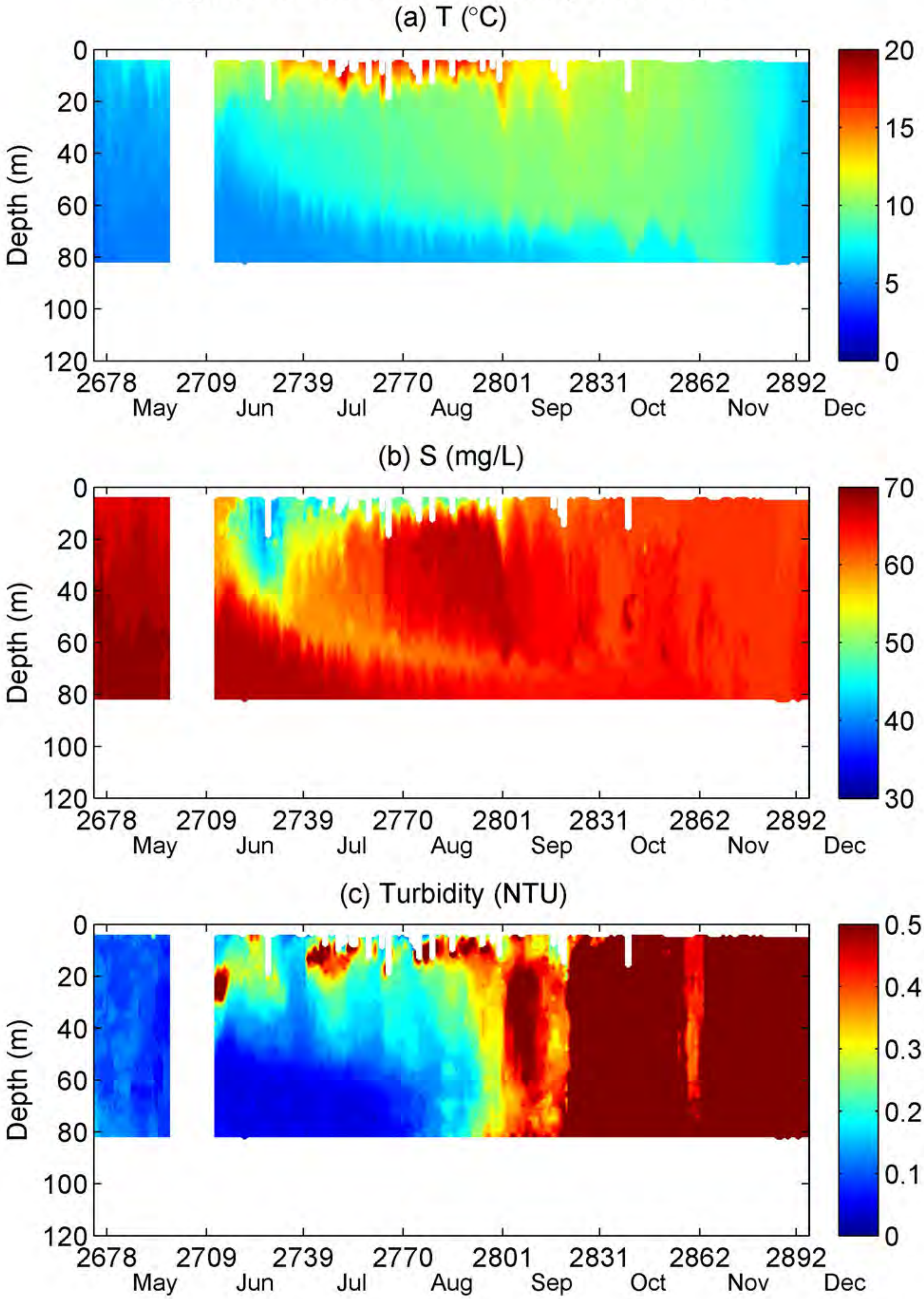
/ocean/rpieters/kr/prof/plot16/profcontcombo2.m fig= 3 2016−Nov−30

Figure 4.7 Rev LA FORME Profiler, May to Nov, 2015



/ocean/rpieters/kr/prof/plot16/profcontcombo2.m fig= 5 2016−Nov−30

Figure 4.8 Rev MID Profiler, May to Nov, 2015



/ocean/rpieters/kr/prof/plot16/profcontcombo2.m fig= 4 2016−Nov−30