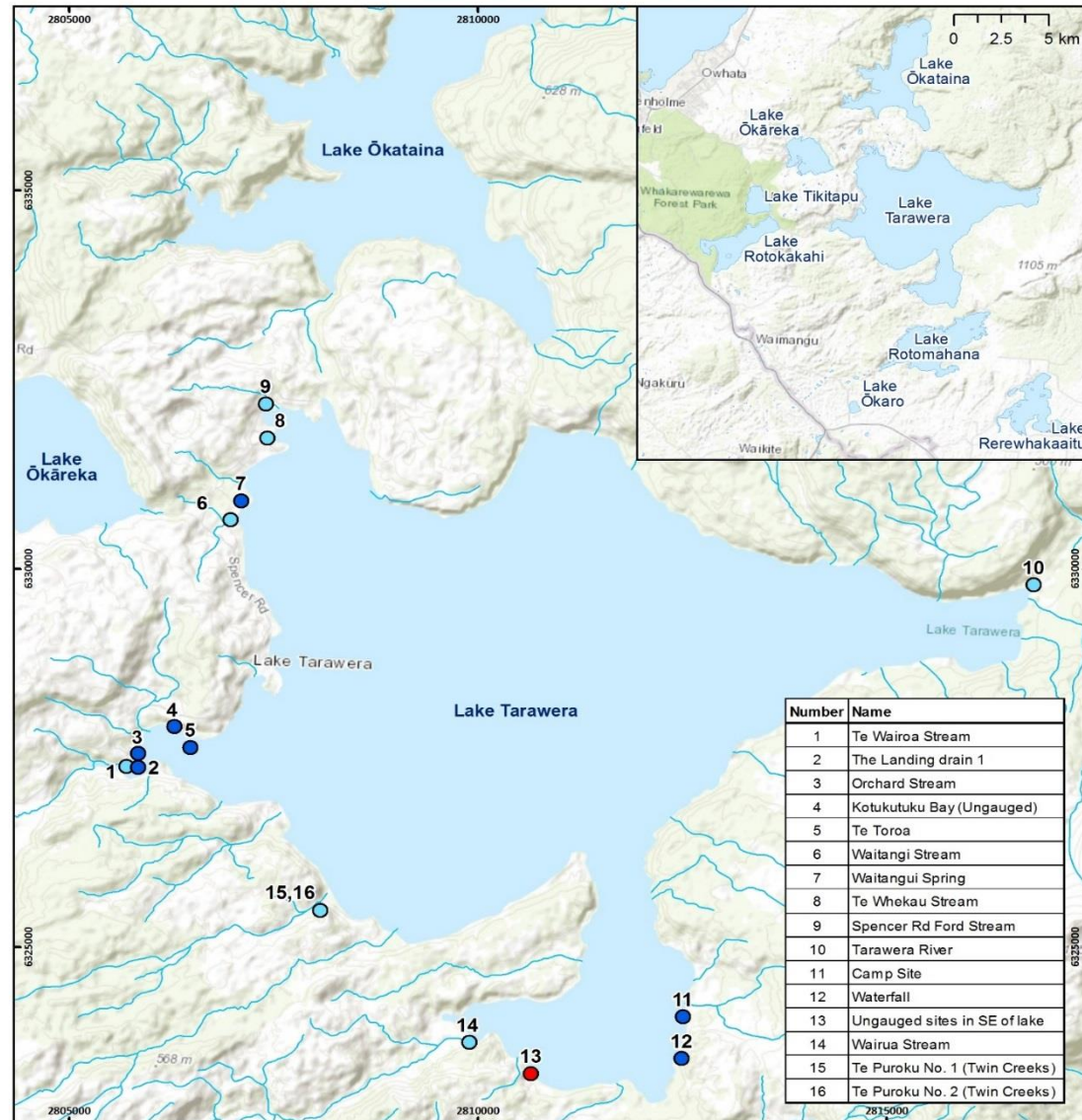


Lake Tarawera



Number	Name
1	Te Wairoa Stream
2	The Landing drain 1
3	Orchard Stream
4	Kotukutuku Bay (Ungauged)
5	Te Toroa
6	Waitangi Stream
7	Waitangui Spring
8	Te Whekau Stream
9	Spencer Rd Ford Stream
10	Tarawera River
11	Camp Site
12	Waterfall
13	Ungauged sites in SE of lake
14	Wairua Stream
15	Te Puroku No. 1 (Twin Creeks)
16	Te Puroku No. 2 (Twin Creeks)

Legend

- Cold spring
- Geothermal spring
- Stream



MAP SHOULD NOT BE USED FOR LEGAL OR NAVIGATIONAL PURPOSES



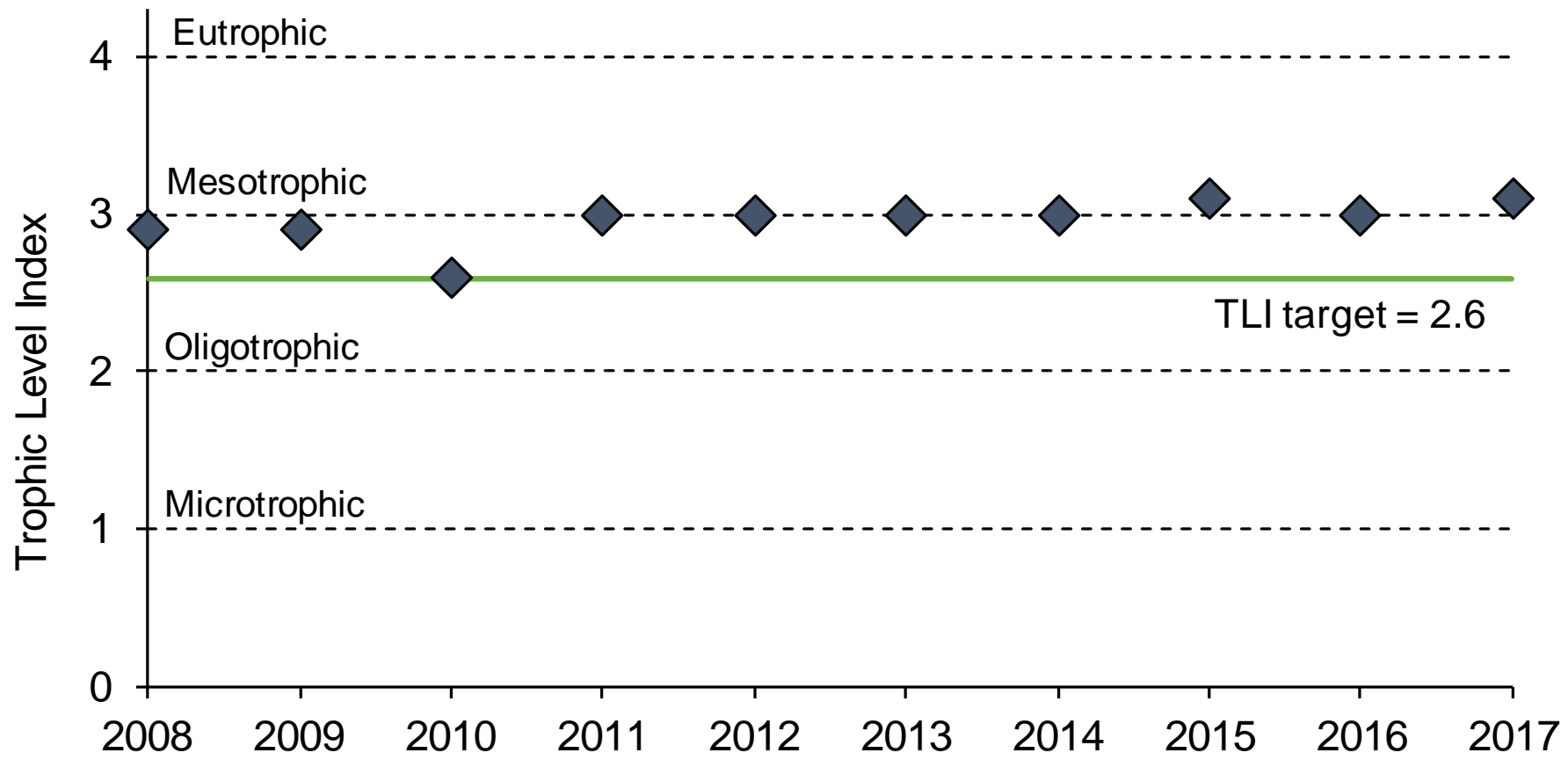
NO.	DATE	REVISION	BY
1	06/02/2017	10044 andrews, 40/10/2017	CGA
2			
3			
4			

Date Saved: 06/12/2017
Coordinate System: GD 1948 New Zealand Map Grid

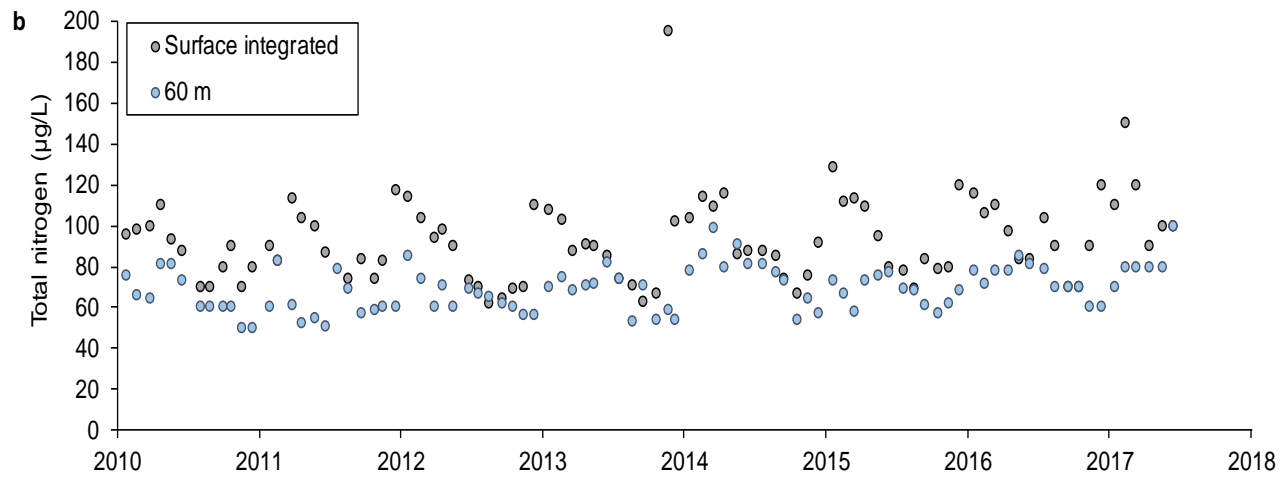
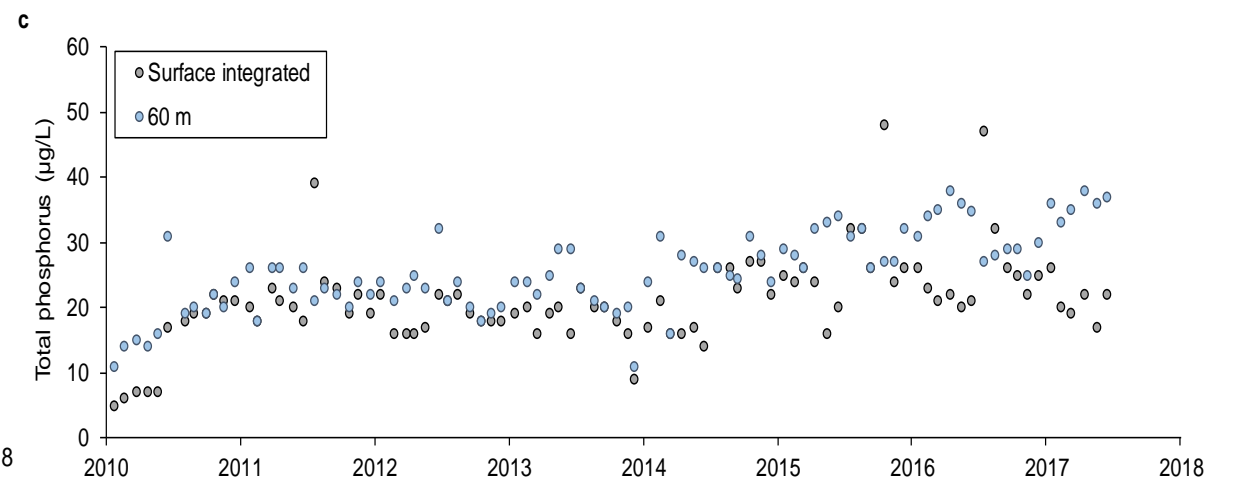
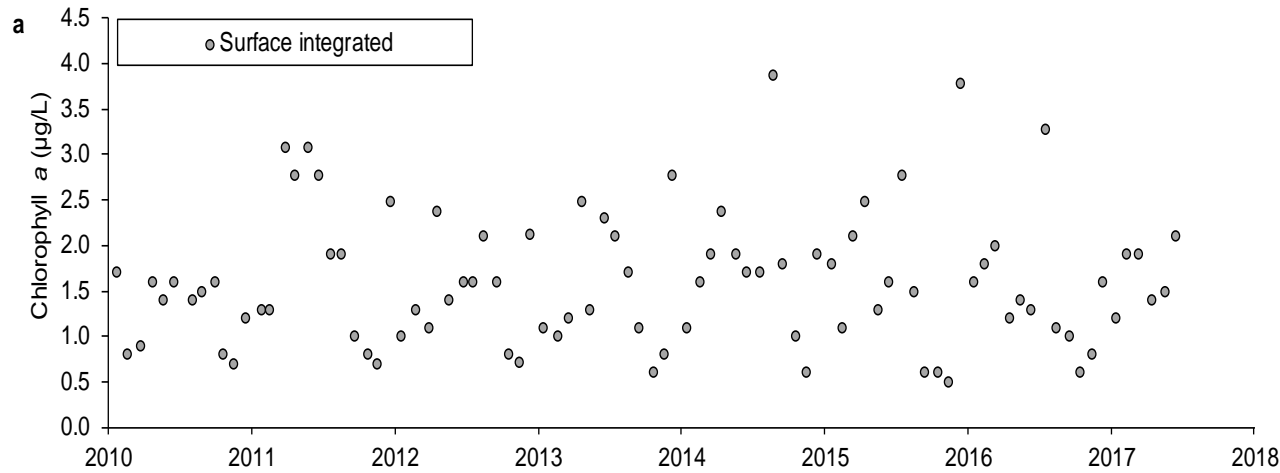


Map 1

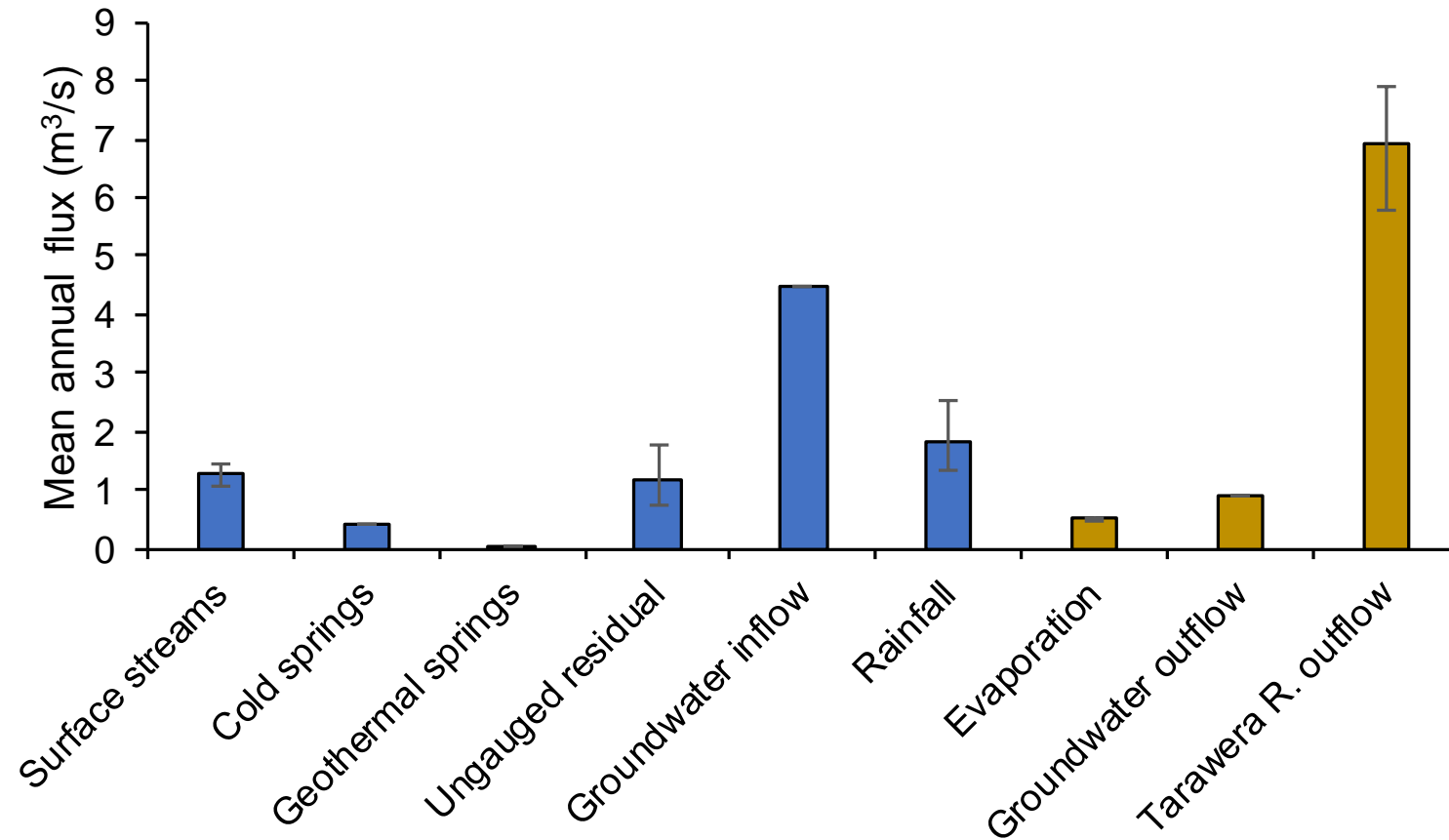
Annual Trophic Level Index (TLI) values for Lake Tarawera. Data from BoPRC (2015) and <http://www.rotorualakes.co.nz> (accessed January 2018).



Lake Tarawera water quality data, 2010–2017. Data provided by BoPRC



**Summary of inflows (blue) and outflows (yellow) in the lake water balance.
Vertical bars denote the range of annual mean values for the period 2009–2017**



Summary of inflows and outflows that were simulated in the model

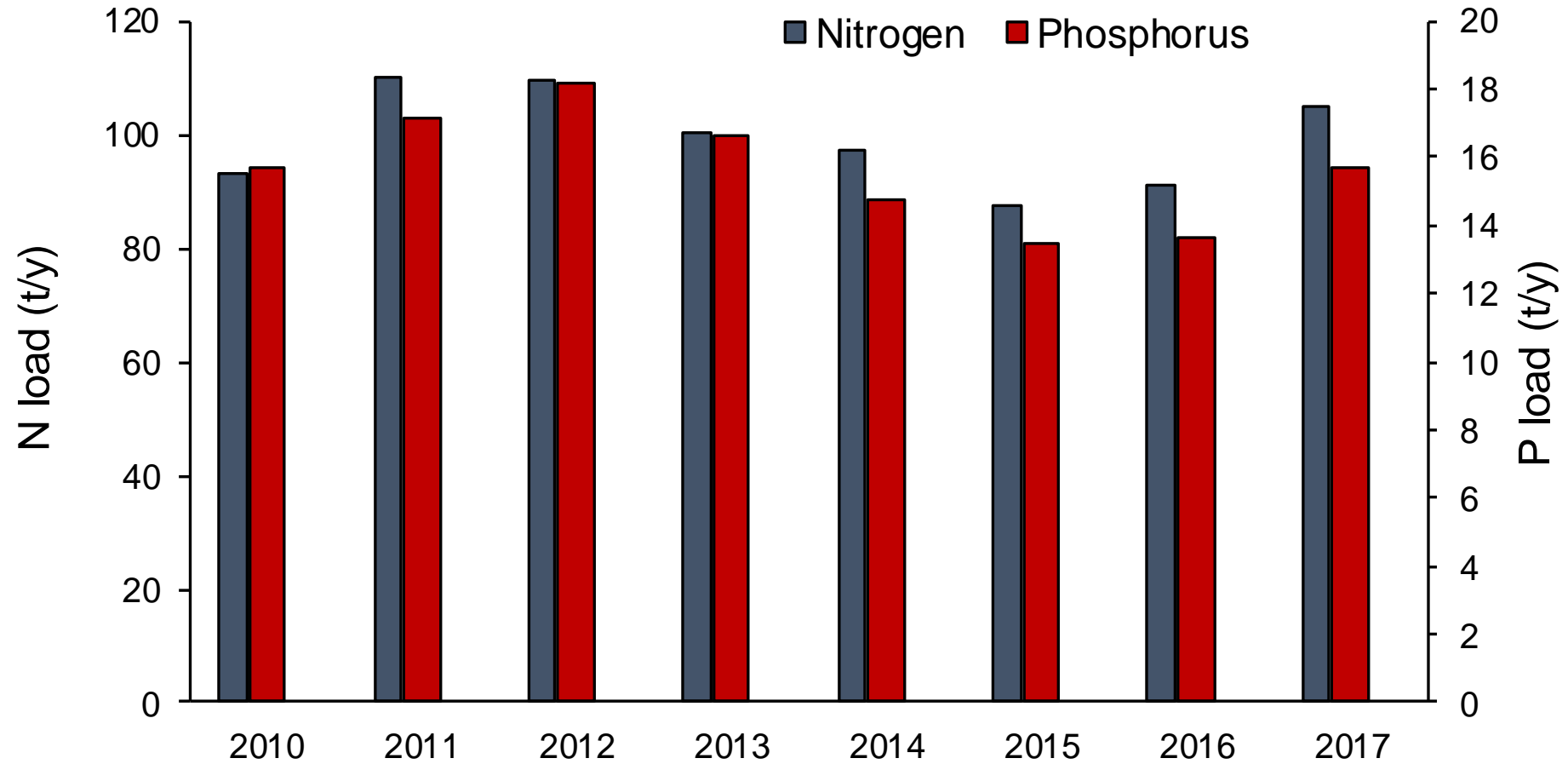
# (Map 1)	Inflow/ outflow	Name	Type	Mean discharge (m ³ /s)	Source	Method to estimate daily mean discharge
1	Inflow	Te Wairoa Stream	Stream	0.347	Table 4.1 in White et al. (2016)	Daily mean Q estimated based on a linear relationship with outflow
2	Inflow	The Landing Drain 1	Cold spring	0.032	Table 4.1 in White et al. (2016)	Assumed constant
3	Inflow	Orchard Stream	Cold spring	0.016	Table 4.1 in White et al. (2016)	Assumed constant
4	Inflow	Kotukutuku Bay (various)	Cold spring	0.010	Table 4.1 in White et al. (2016)	Assumed constant
5	Inflow	Te Toroa	Cold spring	0.091	Table 4.1 in White et al. (2016)	Assumed constant
6	Inflow	Waitangi Stream	Stream	0.164	Table 4.1 in White et al. (2016)	Daily mean Q estimated based on a linear relationship with outflow
7	Inflow	Waitangui Spring	Cold spring	0.004	Table 4.1 in White et al. (2016)	Assumed constant
8	Inflow	Te Whekau Stream	Stream	0.020	Table 4.1 in White et al. (2016)	Mean Q based on White et al. (2016); daily variation based on Te Wairoa Stream
9	Inflow	Spencer Rd Ford Stream	Stream	0.002	Table 4.1 in White et al. (2016)	Assumed constant. Mean Q is low and field measurements were unavailable.
11	Inflow	Camp Site	Cold spring	0.065	Table 4.1 in White et al. (2016)	Assumed constant
12	Inflow	Waterfall	Cold spring	0.174	Table 4.1 in White et al. (2016)	Assumed constant
13	Inflow	Ungauged sites in SE of lake	Geothermal spring	0.010	Table 4.1 in White et al. (2016)	Assumed constant
14	Inflow	Wairua Stream	Stream	0.208	Table 4.1 in White et al. (2016)	Daily mean Q estimated based on a linear relationship with outflow
15	Inflow	Te Puroku No. 1 (Twin Creeks)	Stream	0.123	Table 4.1 in White et al. (2016)	Assumed constant. Q exhibited low variability and was not correlated with other streams.
16	Inflow	Te Puroku No. 2 (Twin Creeks)	Stream	0.384	Table 4.1 in White et al. (2016)	Assumed constant. Q exhibited low variability and was not correlated with other streams.
N/A	Inflow	Groundwater to lake bed	Groundwater	4.456	Calculated from Table 4.5, White et al. (2016)	Assumed constant
N/A	Inflow	Rainfall to lake surface	Rainfall	1.810	Rotorua Airport (Met Service)	Calculated based on daily total rainfall and lake area
10	Outflow	Tarawera River	Stream	6.938	NiWA (Walter pers. comm. 2017)	Gauged values assigned to each day
N/A	Outflow	Groundwater through lake bed	Groundwater	0.918	Table 2.3 in White et al. (2016)	Assumed constant, with minor adjustments to balance residual term
N/A	Inflow	Ungauged residual inflow	Surface runoff (assumed)	1.178	Water balance	Calculated by subtraction

¹ Q_i, j : mean discharge (m³/s) in stream i on day j ; Q_o, j : mean discharge (m³/s) measured at the lake outflow on day j

Summary of nutrient concentrations measured in inflows to Lake Tarawera, 2006–2017

# (Map 1)	Inflow	Total P (mg/L)				PO ₄ -P (mg/L)				Total N (mg/L)				NH ₄ -N (mg N/L)				NO _x -N (mg N/L)			
		Median	Mean	Std. dev.	<i>n</i>	Median	Mean	Std. dev.	<i>n</i>	Median	Mean	Std. dev.	<i>n</i>	Median	Mean	Std. dev.	<i>n</i>	Median	Mean	Std. dev.	<i>n</i>
1	Te Wairoa Stream	0.032	0.060	0.071	30	0.009	0.015	0.017	28	0.282	0.316	0.121	30	0.020	0.022	0.017	28	0.040	0.073	0.087	28
2	The Landing Drain 1	0.071	0.106	0.086	29	0.040	0.038	0.015	30	0.375	0.399	0.123	30	0.006	0.010	0.010	29	0.237	0.231	0.091	30
3	Orchard Stream	0.076	0.109	0.095	18	0.042	0.043	0.017	16	0.496	0.493	0.160	18	0.011	0.015	0.012	15	0.293	0.293	0.118	16
4	Kotukutuku Bay (various)	0.081	0.108	0.076	59	0.062	0.058	0.016	55	1.355	1.299	0.645	59	0.006	0.011	0.011	53	0.918	1.002	0.448	55
5	Te Toroa	0.074	0.094	0.055	30	0.049	0.045	0.016	30	1.746	1.810	0.455	30	0.007	0.012	0.011	29	1.348	1.325	0.457	30
6	Waitangi Stream	0.024	0.044	0.065	27	0.008	0.013	0.014	25	0.282	0.293	0.132	27	0.014	0.016	0.014	25	0.032	0.067	0.075	25
7	Waitangui Spring	0.082	0.104	0.078	28	0.048	0.053	0.025	27	0.249	0.243	0.063	28	0.008	0.013	0.011	26	0.073	0.085	0.059	27
8	Te Whekau Stream	0.078	0.094	0.055	30	0.047	0.044	0.020	30	1.718	1.766	0.499	30	0.020	0.020	0.012	29	1.345	1.231	0.559	30
9	Spencer Rd Ford Stream	0.100	0.117	0.077	30	0.024	0.025	0.018	27	0.623	0.600	0.267	29	0.079	0.078	0.041	28	0.334	0.349	0.160	28
11	Camp Site	0.142	0.191	0.115	30	0.114	0.124	0.063	30	0.270	0.281	0.111	30	0.007	0.010	0.010	29	0.133	0.131	0.054	30
12	Waterfall	0.136	0.164	0.070	29	0.113	0.114	0.035	27	0.270	0.293	0.124	28	0.006	0.010	0.010	26	0.140	0.142	0.069	27
13	Ungauged sites in SE of lake	0.425	0.415	0.146	29	0.303	0.309	0.078	29	0.461	0.479	0.137	29	0.116	0.116	0.024	28	0.241	0.260	0.113	29
14	Wairua Stream	0.094	0.103	0.040	26	0.075	0.071	0.020	26	0.617	0.621	0.159	26	0.012	0.015	0.010	26	0.492	0.463	0.149	26
15	Te Puroku No. 1 (Twin Creeks)	0.054	0.091	0.092	30	0.040	0.043	0.035	28	0.550	0.548	0.165	30	0.009	0.013	0.012	27	0.386	0.356	0.127	28
16	Te Puroku No. 2 (Twin Creeks)	0.062	0.086	0.078	29	0.037	0.036	0.011	28	0.486	0.511	0.173	29	0.007	0.012	0.012	28	0.357	0.358	0.114	28

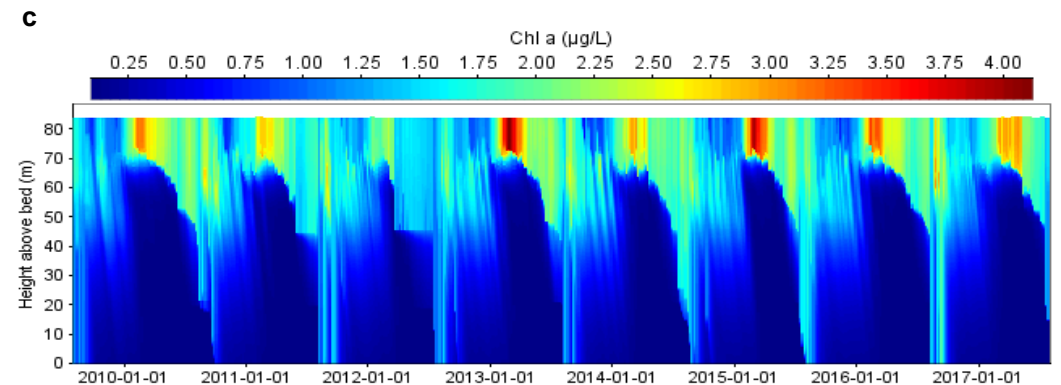
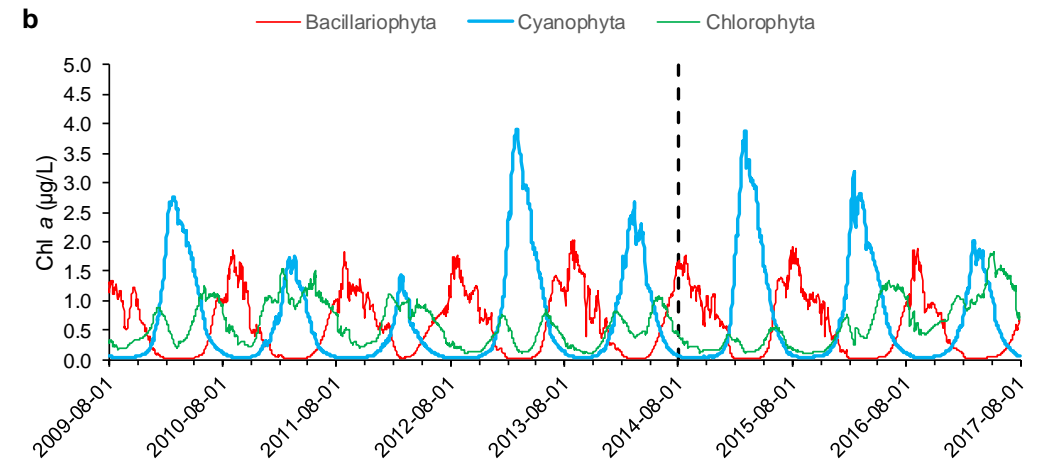
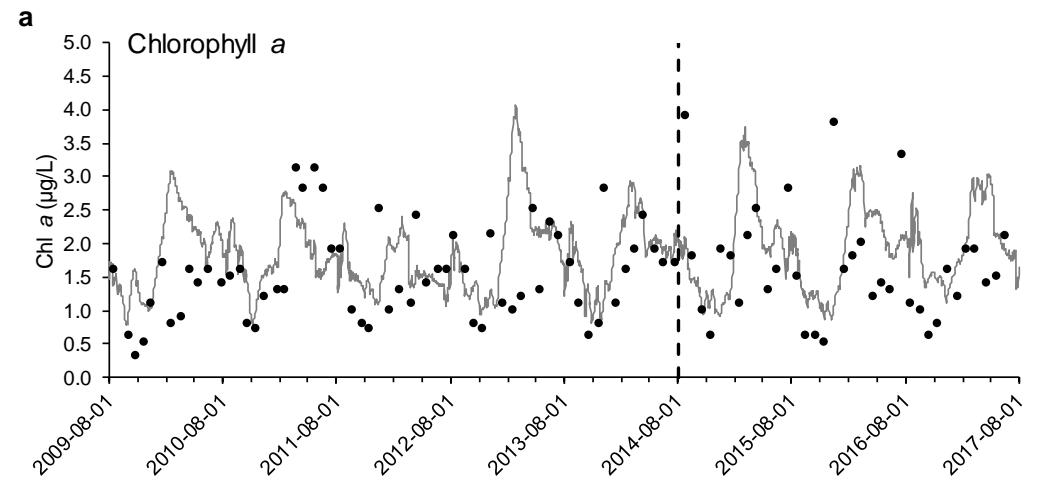
Estimated annual external nutrient loads to Lake Tarawera



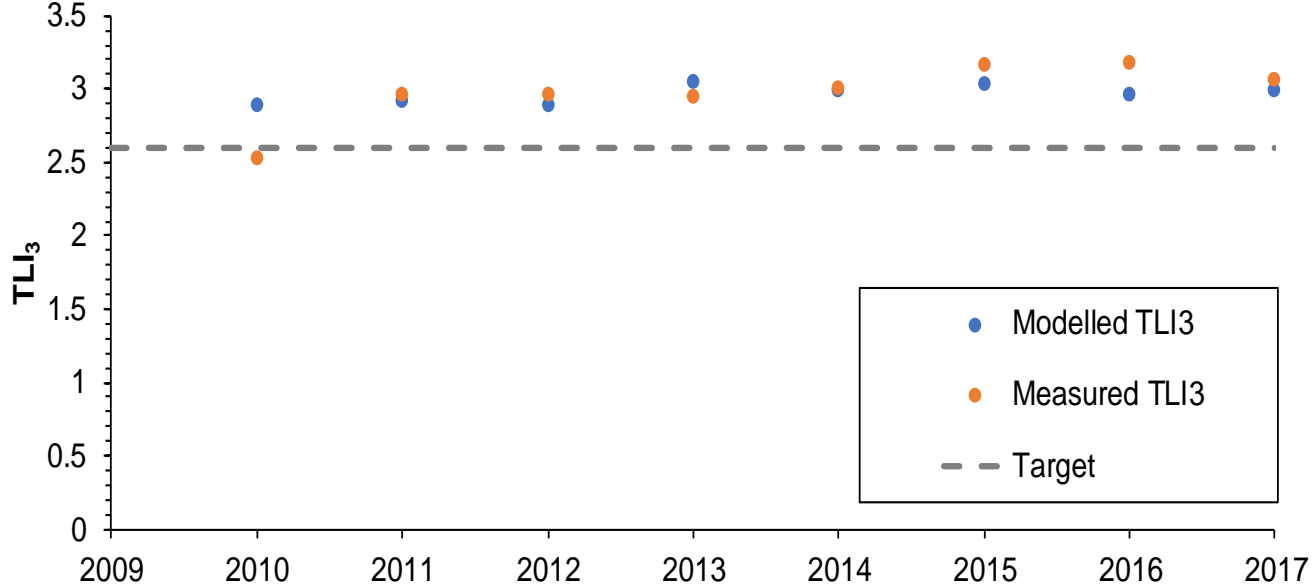
Comparison of estimated external nutrient loads to Lake Tarawera

Study	TN (t/y)	TP (t/y)	Comments
This study	99.18	15.6	Average for 2009–2017
Lake Tarawera Action Plan (BoPRC 2015)	94.85	11.39	Inner catchment based on Hamilton (2014); outer catchment calculated separately. Geothermal P load assumed to be 5 t/yr but is "an estimate only"
Hamilton et al. (2006)	84.6	10.41	Based on land use export coefficients
Hamilton et al. (2006)	96.2	12.7	Based on stream sampling
Dada et al. (2016)	85.0	10.6	Partly based on land use export coefficients
Donovan and Donovan (2003)	91.43	17.53	Geothermal P loads assumed to be 12 t/yr but recognises that they could be in the range 4-20 t/yr

a) Modelled (lines) and measured (circles) chlorophyll a at the surface, b) simulated succession of three modelled phytoplankton taxa, c) modelled chlorophyll a concentrations at all depths. The dashed line denotes the division between the calibration (2010–2014) and validation (2015–2017) periods.

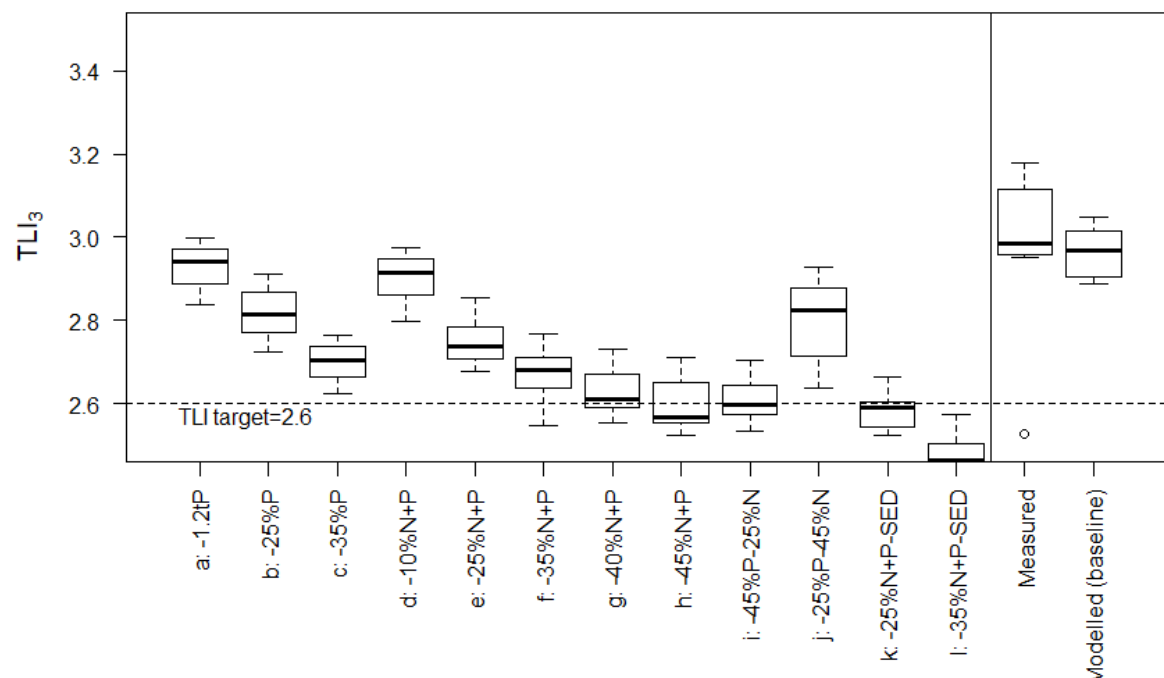


Modelled and measured annual TLI₃ values for baseline conditions

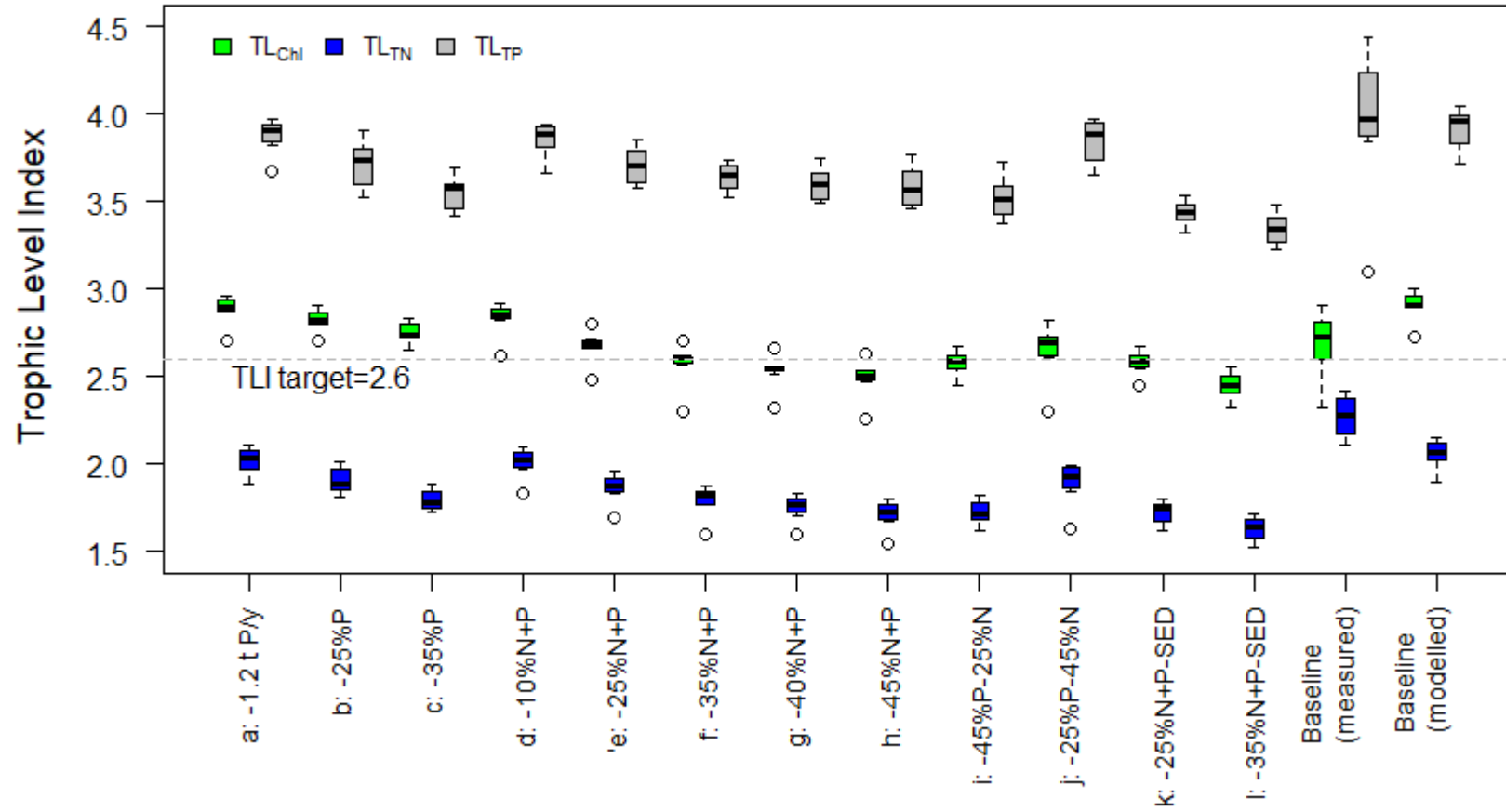


Modelled annual TLI₃ values for 2010–2017

Scenario	Description	Mean annual load (t/y)		↓ max. sediment release?	Reduction in load from baseline (t/y)		TLI ₃			TLI*			
		TN	TP		TN	TP	Mean	Min.	Max.	Mean	Min.	Max.	
-	Baseline	Baseline simulation	99.18	15.64	No	0.0	0.00	2.96	2.89	3.05	2.93	2.74	3.04
a	-1.2tP	Reduce annual P loads by 1.2 t	99.18	14.44	No	0.0	1.20	2.93	2.84	3.00	2.92	2.82	2.99
b	-25%P	Reduce average P loads by 25%	99.18	11.73	No	0.0	3.91	2.82	2.72	2.91	2.82	2.74	2.91
c	-35%P	Reduce average P loads by 35%	99.18	10.17	No	0.0	5.48	2.70	2.63	2.76	2.71	2.65	2.78
d	-10%N+P	Reduce average N and P loads by 10%	89.26	14.08	No	9.9	1.56	2.90	2.80	2.98	2.89	2.75	2.96
e	-25%N+P	Reduce average N and P loads by 25%	74.38	11.73	No	24.8	3.91	2.75	2.68	2.86	2.73	2.63	2.84
f	-35%N+P	Reduce average N and P loads by 35%	64.46	10.17	No	34.7	5.48	2.67	2.55	2.77	2.65	2.49	2.75
g	-40%N+P	Reduce average N and P loads by 40%	59.51	9.39	No	39.7	6.26	2.63	2.55	2.73	2.61	2.50	2.71
h	-45%N+P	Reduce average N and P loads by 45%	54.55	8.60	No	44.6	7.04	2.60	2.52	2.71	2.57	2.46	2.69
i	-25%N-45%P	Reduce average P load by 45%, N load by 25%	74.38	8.60	No	24.8	7.04	2.61	2.53	2.70	2.60	2.53	2.60
j	-45%N-25%P	Reduce average P load by 25%, N load by 55%	54.55	11.73	No	44.6	3.91	2.80	2.64	2.93	2.76	2.90	2.90
k	-25%N+P-SED	Reduce average N and P loads by 25%, sediment release to near 0 (reduce by 90%)	74.38	11.73	Yes	24.8	3.91	2.58	2.52	2.66	2.58	2.51	2.67
l	-35%N+P-SED	Reduce average N and P loads by 35%, sediment release to near 0 (reduce by 90%)	64.46	10.17	Yes	34.7	5.48	2.48	2.41	2.58	2.47	2.41	2.57



Model results for load reduction scenarios



Uncertainties

Accuracy of laboratory data

Groundwater nutrient loads

Sediment release

Spatial variability in water quality

Climate change

Groundwater lags: