Supplementary Materials

Table S1. Discharge calibration parameters: definitions, ranges and fitted values for different calibration areas.

Name	Definition	Range		Default	Fitted Values									
		Min	Max	Value	LucKLU	KraWSW	CzWJAN	PilSZC	KrzBON	CzMDAB	PilWAS	ZebBON	PilPRZ	PilSUL
v__SURLAG.bsn	Surface runoff lag coefficient (-)	1	4	4	2.71	2.71	2.71	2.71	2.71	2.71	2.71	2.71	2.71	2.71
v__CNCOEF.bsn	Plant ET curve number coefficient (-)	0.5	2	1	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45
v__TIMP.bsn	Snow pack temperature lag factor (-)	0	1	1	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
v__SNOCOVMX.bsn	Minimum snow water content that corresponds to 100% snow cover (mm)	5	40	1	14.51	14.51	14.51	14.51	14.51	14.51	14.51	14.51	14.51	14.51
v__SMTMP.bsn	Snow melt base temperature (°C)	−1	1.5	0.5	−0.94	−0.94	−0.94	−0.94	−0.94	−0.94	−0.94	−0.94	−0.94	−0.94
r__CN2.mgt	Initial SCS runoff curve number for moisture condition II (-)	−0.1	0.1	30 − 90	0.09	−0.03	0.07	−0.08	−0.11	0.01	0.01	0.01	0.02	0.02
r__ALPHA_BF.gw	Baseflow alpha factor ($1 \cdot days^{-1}$)	−0.7	0.7	0.048	−0.57	−0.33	0.63	0.33	0.55	0.14	−0.19	−0.19	0.65	0.65
r__GW_DELAY.gw	Groundwater delay time (days)	−0.5	0.5		0.34	0.26	−0.32	0.12	0.01	−0.06	0.44	0.44	−0.20	−0.20
a__GWQMN.gw	Threshold depth of water in the shallow aquifer required for return flow to occur (mm H_2O)	−200	200	1000	−140.60	132.20	24.60	20.20	26.10	71.80	−64.60	−64.60	15.00	15.00
r__GW_REVAP.gw	Groundwater "revap" coefficient (-)	−0.5	0.5	0.02	−0.09	−0.35	0.39	0.08	0.13	0.38	0.46	0.46	0.04	0.04
r__RCHRG_DP.gw	Deep aquifer percolation fraction (-)	−0.5	0.5	0.05	0.33	−0.42	0.35	0.30	0.15	0.30	−0.09	−0.09	−0.48	−0.48
v__ESCO.hru	Soil evaporation compensation factor (-)	0.75	1	0.95	0.93	0.76	0.88	0.97	0.83	1.00	0.88	0.88	0.82	0.82
v__EPCO.hru	Plant uptake compensation factor (-)	0	1	1	0.78	0.97	0.38	0.67	0.36	0.95	0.15	0.15	0.05	0.05
r__SLSUBBSN.hru	Average slope length (m)	−0.5	0.5	50	0.21	0.48	0.17	0.18	−0.12	−0.40	−0.12	-0.12	-0.21	-0.21
r__CH_N2.rte	Manning's "n" value for the main channel (-)	−0.5	0.5	0.014	0.08	−0.45	−0.49	−0.42	−0.48	0.38	0.31	0.31	0.43	0.43
r__CH_N1.sub	Manning's "n" value for the tributary channel (-)	−0.5	0.5	0.014	0.45	0.42	−0.26	−0.35	0.16	−0.15	0.27	0.27	0.10	0.10
r__SOL_Z().sol	Depth from soil surface to bottom of layer (mm)	−0.3	0.3	250–1000	0.29	−0.29	0.07	0.27	0.07	0.25	0.23	0.23	0.03	0.03
r__SOL_K().sol	Saturated hydraulic conductivity ($mm \cdot hr^{-1}$)	−0.5	0.5	0.03–500	0.25	−0.20	0.26	0.24	−0.40	−0.25	0.26	0.26	−0.43	−0.43
r__SOL_BD().sol	Moist bulk density ($g \cdot cm^{-3}$)	−0.3	0.3	0.7–2.1	0.21	0.04	−0.08	0.19	0.06	0.08	0.25	0.25	0.06	0.06

Notes: "r__"—indicates relative change; "v__"—indicates replacement by a new value; "a__"—indicates additive change; suffixes.".gw", ".rte," *etc.*—SWAT file extensions.

Table S2. NO_3-N loads calibration parameters: definitions, ranges and fitted values for different calibration areas.

Name	Definition	Range		Default	Fitted Values					
		Min	Max	Value	LucPRZ	CzMOST	CzWCIE	KrzTEG	PilSZC/PilLAK	PilSUL
v__ERORGN.hru	Organic N enrichment ratio for loading with sediment (-)	5	8	0	6.81	7.53	7.71	6.15	5.45	6.03
v__BIOMIX.mgt	Biological mixing efficiency (-)	0	0.7	0.2	0.18	0.93	0.94	0.89	0.78	0.53
r__BZ_AREA.sep	Average area of drainfield of individual septic systems (m^2)	−0.3	0.3	100–20,000	−0.11	−0.29	0.12	−0.24	−0.16	−0.14
v__HLIFE_NGW.gw	Half-life of nitrate in the shallow aquifer (days)	18	30	0	22.25	27.17	20.39	20.00	28.93	19.59
r__SOL_NO3().chm	Initial NO_3 concentration in the soil layer ($mg\ N \cdot kg^{-1}$ soil, dry weight)	−0.5	0.5	2-10	−0.44	−0.03	−0.04	0.47	−0.01	0.22
v__SOL_ORGN().chm	Initial organic N concentration in the soil layer ($mg\ N \cdot kg^{-1}$ soil, dry weight)	400	900	0	998.13	358.13	929.38	991.88	836.88	950.50
r__SOL_CBN().sol	Organic carbon content (% soil weight)	−0.3	0.3	0.24–16	−0.281	0.220	−0.204	−0.276	0.294	−0.16
r__RS4.swq	Rate coefficient for organic N settling in the reach at 20 °C (day^{-1})	−0.3	0.3	0.05	0.108	−0.211	−0.123	0.132	0.009	−0.25
r__BC1.swq	Rate constant for biological oxidation of NH_4 to NO_2 in the reach at 20 °C in well-aerated conditions (day^{-1})	−0.3	0.3	0.55	−0.008	−0.277	0.123	−0.139	0.162	0.21
r__BC2.swq	Rate constant for biological oxidation of NO_2 to NO_3 in the reach at 20 °C in well-aerated conditions (day^{-1})	−0.3	0.3	1.1	0.005	0.008	0.082	0.110	0.144	0.16
r__BC3.swq	Rate constant for hydrolysis of organic N to NH4 in the reach at 20 °C ($1 \cdot day^{-1}$)	−0.3	0.3	0.21	0.069	−0.025	0.280	0.049	−0.095	0.11
v__AI1.wwq	Fraction of algal biomass that is nitrogen ($mg\ N \cdot mg \cdot alg^{-1}$)	0.06	0.09	0.08	0.08	0.08	0.08	0.08	0.08	0.07
v__TFACT.wwq	Fraction of solar radiation computed in the temperature heat balance that is photosynthetically active	0.4	0.9	0.3	0.56	0.56	0.56	0.56	0.56	0.82
v__MUMAX.wwq	Maximum specific algal growth rate at 20 °C (day^{-1})	1.7	3	2	2.68	2.68	2.68	2.68	2.68	2.44

Table S2. *Cont.*

Name	Definition	Range		Default Value	Fitted Values					
		Min	Max		LucPRZ	CzMOST	CzWCIE	KrzTEG	PilSZC/PilLAK	PilSUL
v__CDN.bsn	Denitrification exponential rate coefficient (-)	0.4	2	1.4	1.62	1.62	1.62	1.62	1.62	1.03
v__RCN.bsn	Concentration of nitrogen in rainfall (mg · L^{-1})	1	2	1.4	1.61	1.61	1.61	1.61	1.61	1.44
v__N_UPDIS.bsn	Nitrogen uptake by plants distribution parameter	10	20	20	17.84	17.84	17.84	17.84	17.84	13.62
v__CMN.bsn	Rate factor for humus mineralization of active organic nutrients (-)	0.0003	0.0017	0.0003	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015
v__SDNCO.bsn	Denitrification threshold water content (-)	0.975	0.999	1.1	0.99	0.99	0.99	0.99	0.99	0.99
v__NPERCO.bsn	Nitrate percolation coefficient (-)	0.4	0.98	0.2	0.40	0.40	0.40	0.40	0.40	0.40

Notes: "r__"—indicates relative change; "v__"—indicates replacement by a new value; suffixes. ".gw", ".bsn," *etc*. —SWAT file extensions.

Table S3. TP loads calibration parameters: definitions, ranges and fitted values for different calibration areas.

Name	Definition	Range		Default Value	Fitted Values					
		Min	Max		LucPRZ	CzMOST	CzWCIE	KrzTEG	PilSZC/ PilLAK	PilSUL
r__USLE_K().sol	USLE equation soil erodibility (K) factor.	−0.5	0.2	0.004–0.16	0.04	−0.37	−0.40	0.03	−0.24	0.07
r__SOL_SOLP(). chm	Initial soluble P concentration in soil layer (mg P · kg^{-1} soil or ppm).	−0.5	0.5	0.5–12	−0.49	0.53	0.70	0.26	−0.30	0.03
v__SOL_ORGP ().chm	Initial organic P concentration in soil layer (mg P · kg^{-1} soil or ppm).	0	400	0	229.81	397.51	248.77	190.70	155.34	269.67
v__ERORGP.hru	Phosphorus enrichment ratio for loading with sediment.	0	5	0	5.9	5.37	5.76	0.38	1.05	0.38
r__GWSOLP.gw	Concentration of soluble phosphorus in groundwater contribution to streamflow from subbasin (mg P · L^{-1} or ppm).	−0.5	1	0–0.07	0.48	0.52	0.18	0.94	0.95	0.49
r__USLE_C{}.pl ant.dat	Minimum value of USLE C factor for water erosion applicable to the land cover/plant.	−0.3	0.3	0.03–0.1	−0.16	−0.16	−0.16	−0.16	−0.16	−0.16
v__PPERCO.bsn	Phosphorus percolation coefficient (10 m^{-3} · Mg^{-1}).	10	15	10	14.19	14.19	14.19	14.19	14.19	14.19
v__PHOSKD.bsn	Phosphorus soil partitioning coefficient (m^{-3} · Mg^{-1}).	150	200	175	150.29	150.29	150.29	150.29	150.29	150.29
v__PSP.bsn	Phosphorus availability index.	0.01	0.7	0.4	0.24	0.24	0.24	0.24	0.24	0.24

Notes: "r__"—indicates relative change; "v__"—indicates replacement by a new value; suffixes ".chm", ".gw," *etc*.—SWAT file extensions.

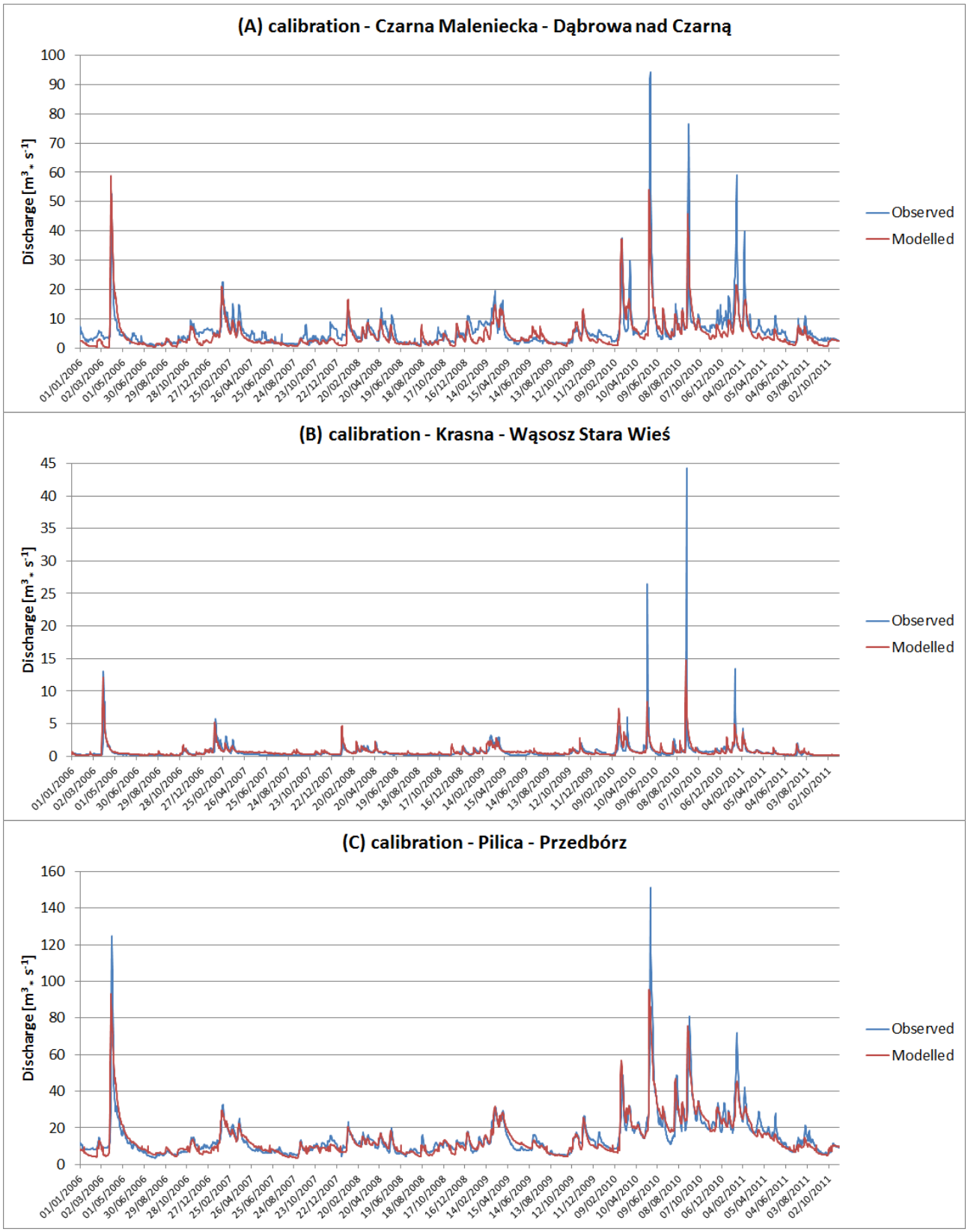
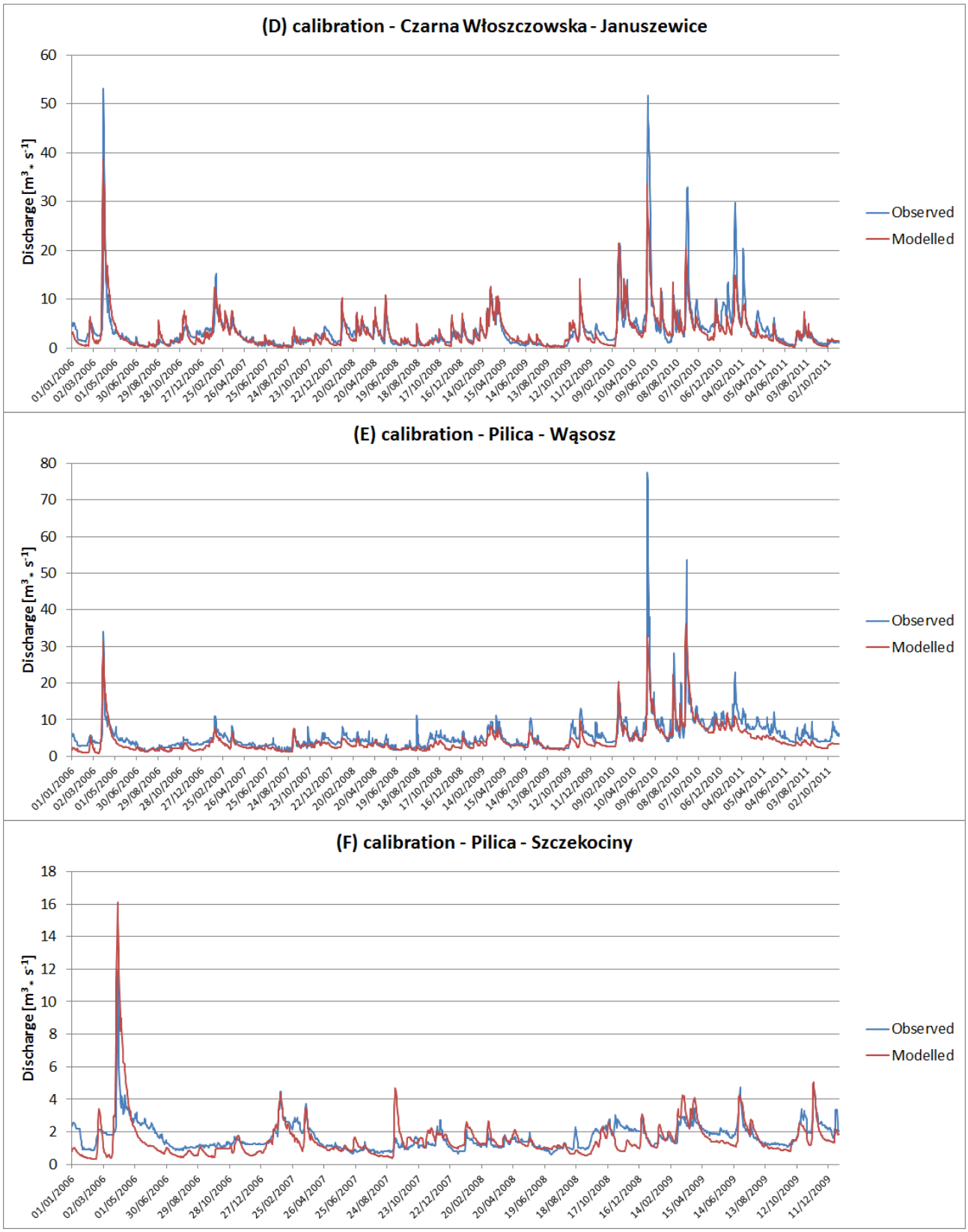


Figure S1. *Cont.*



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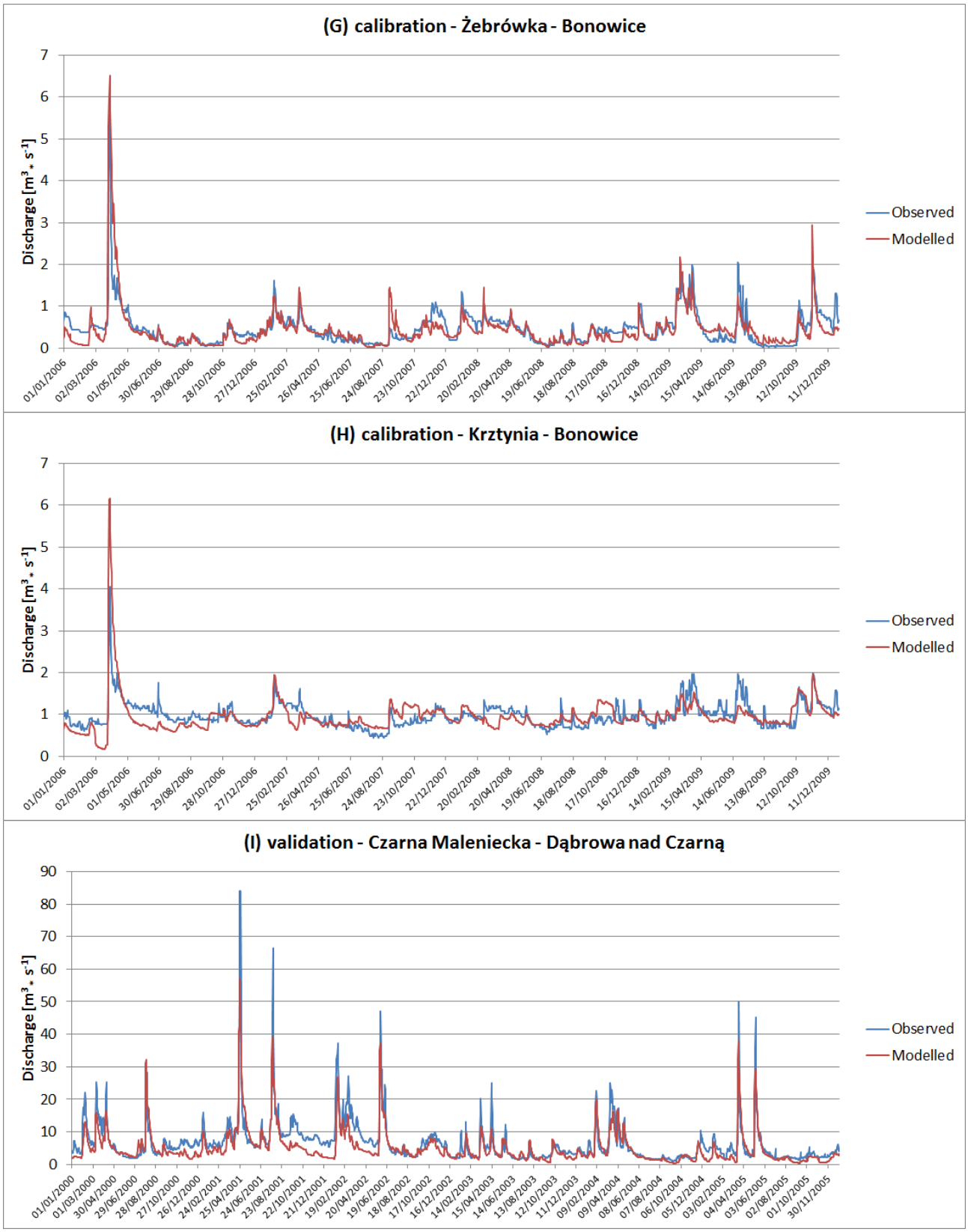

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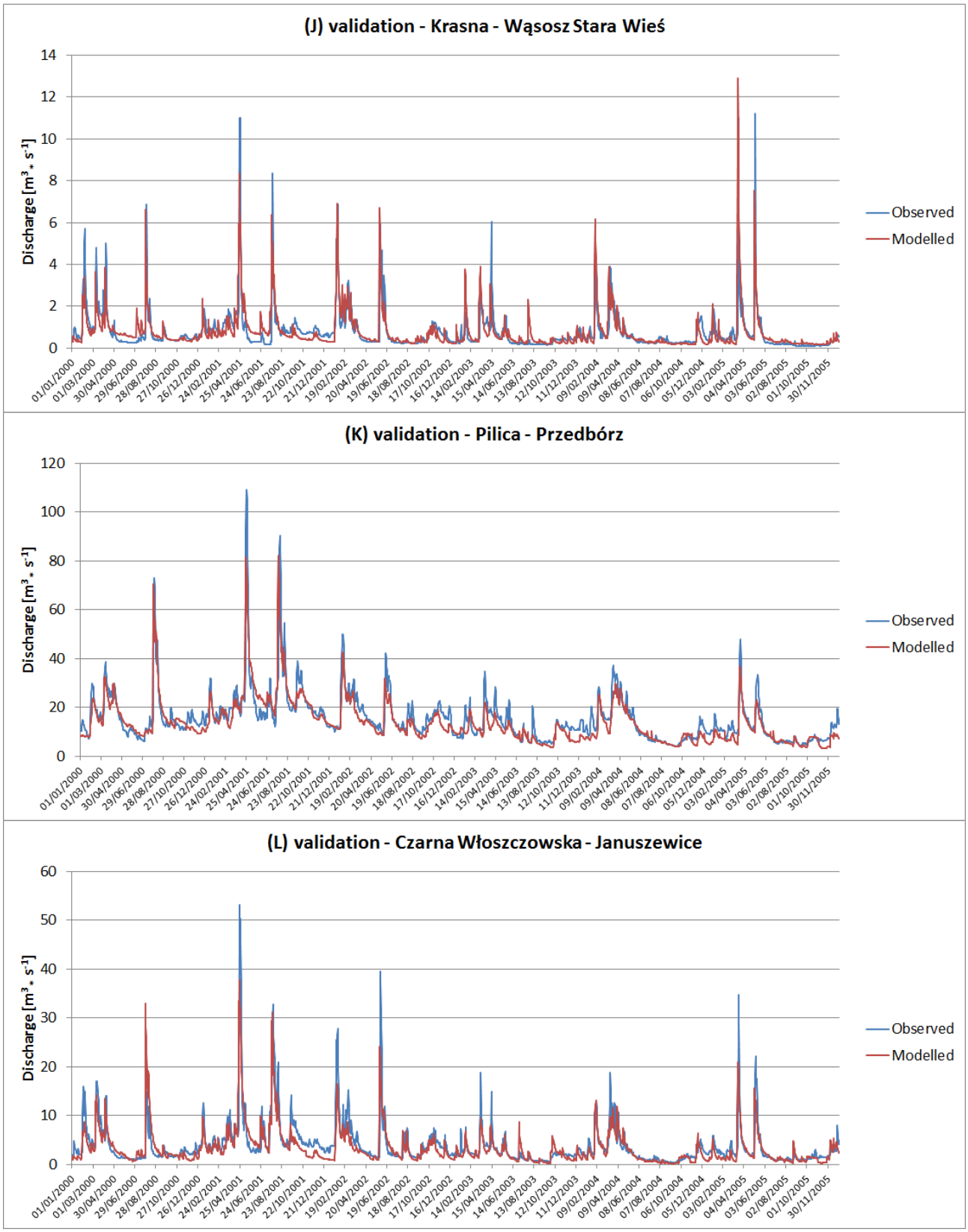

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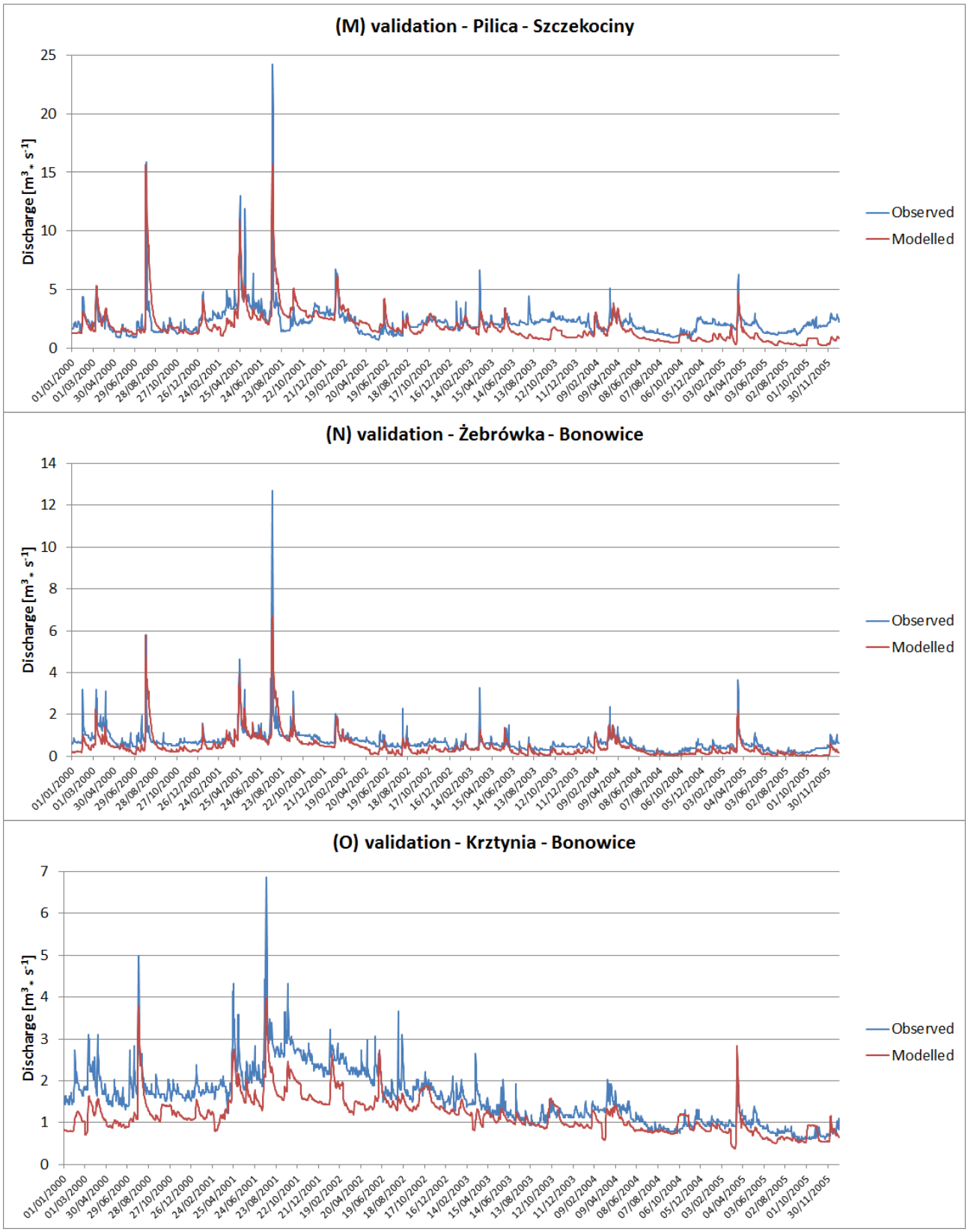
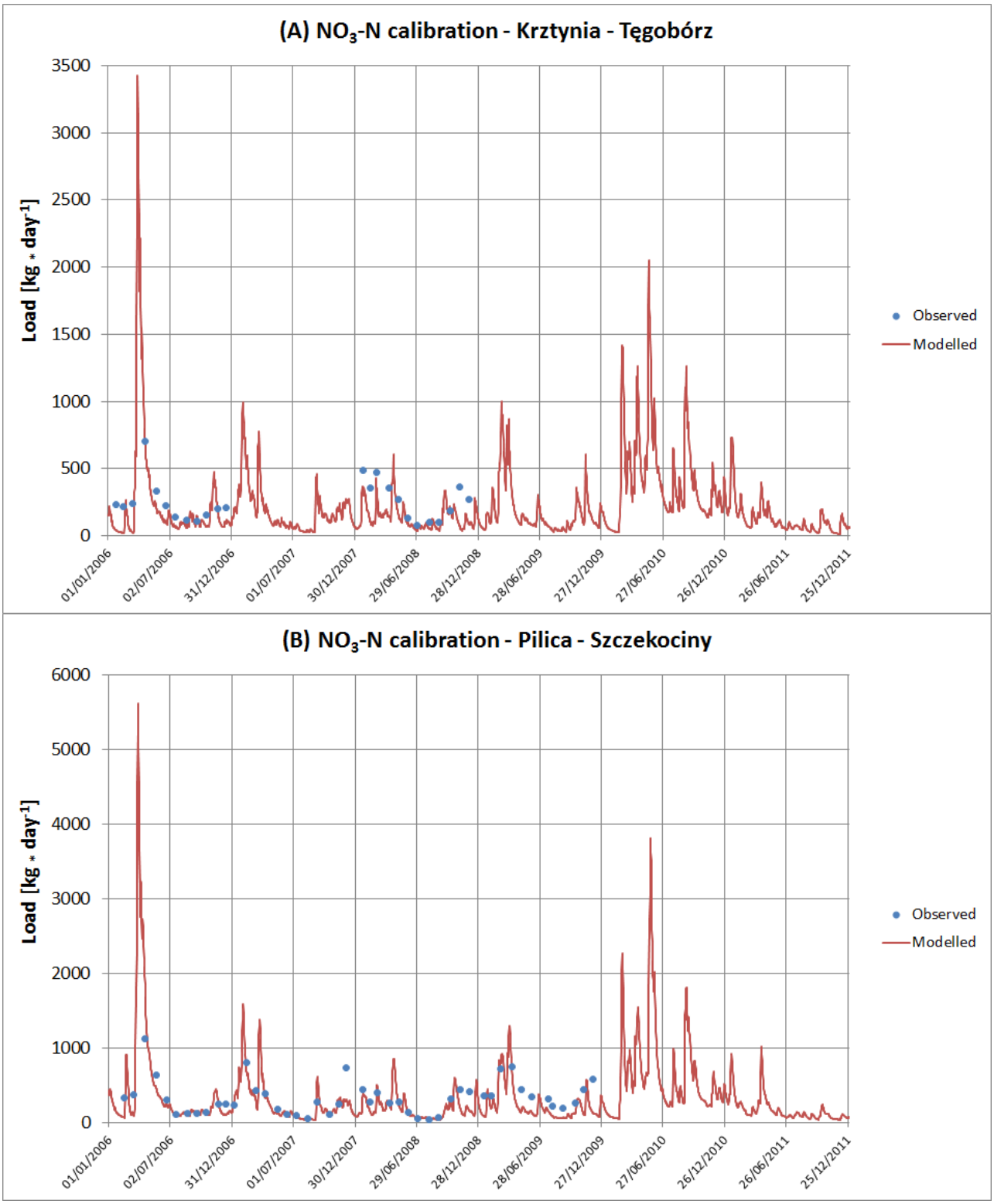


Figure S1. Calibration and validation plots for daily discharge at the SRC gauging stations.



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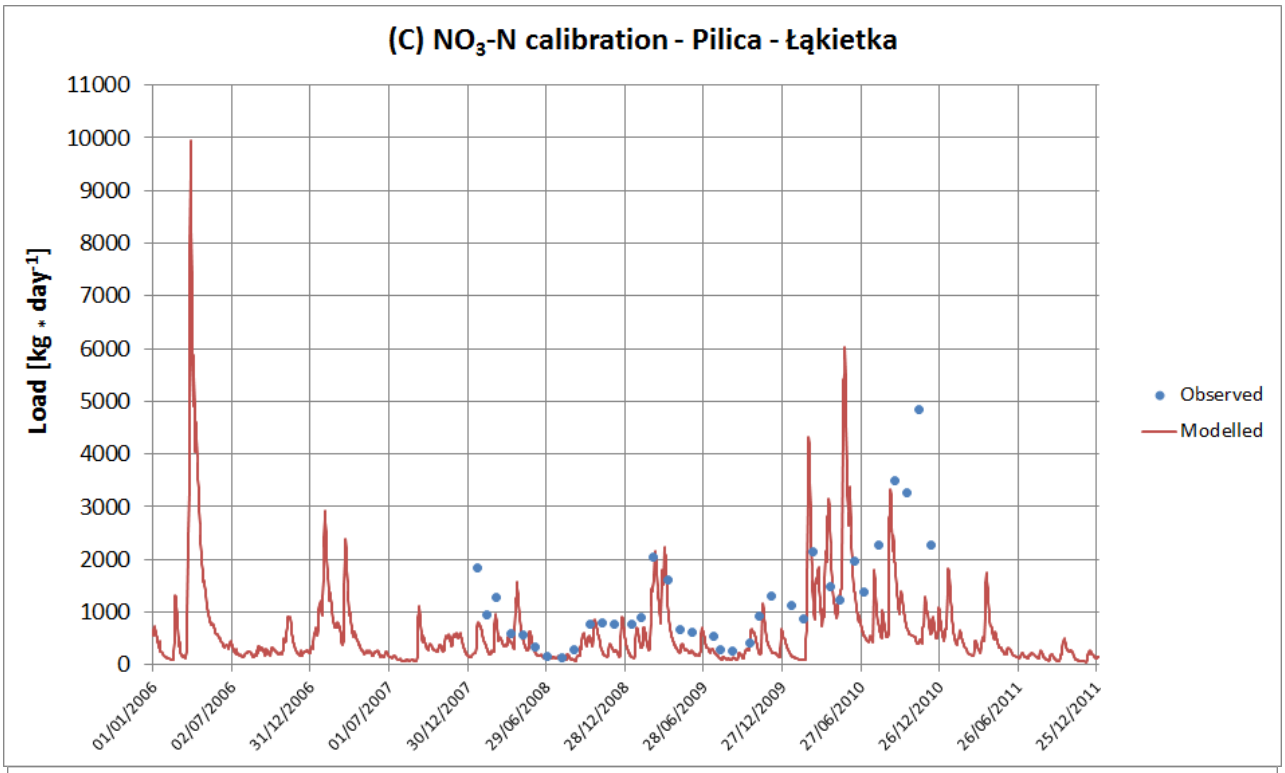


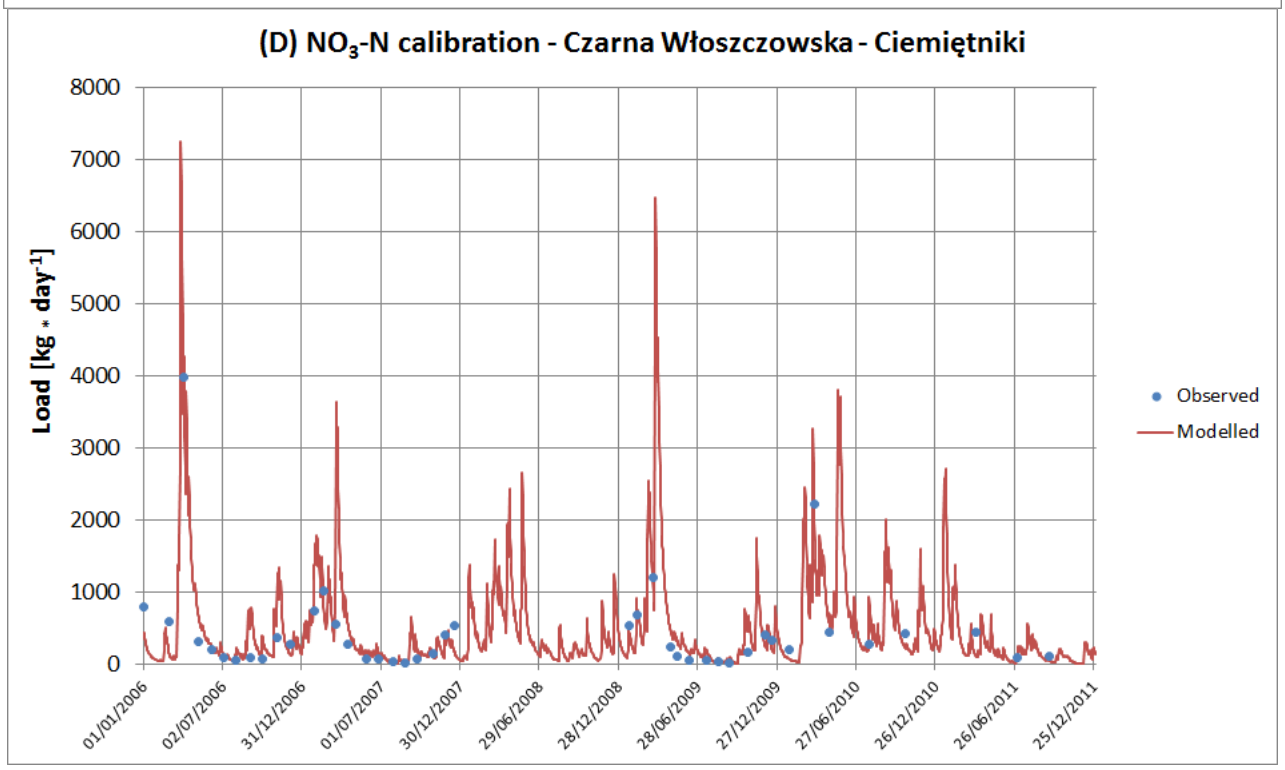


Figure S2. *Cont.*

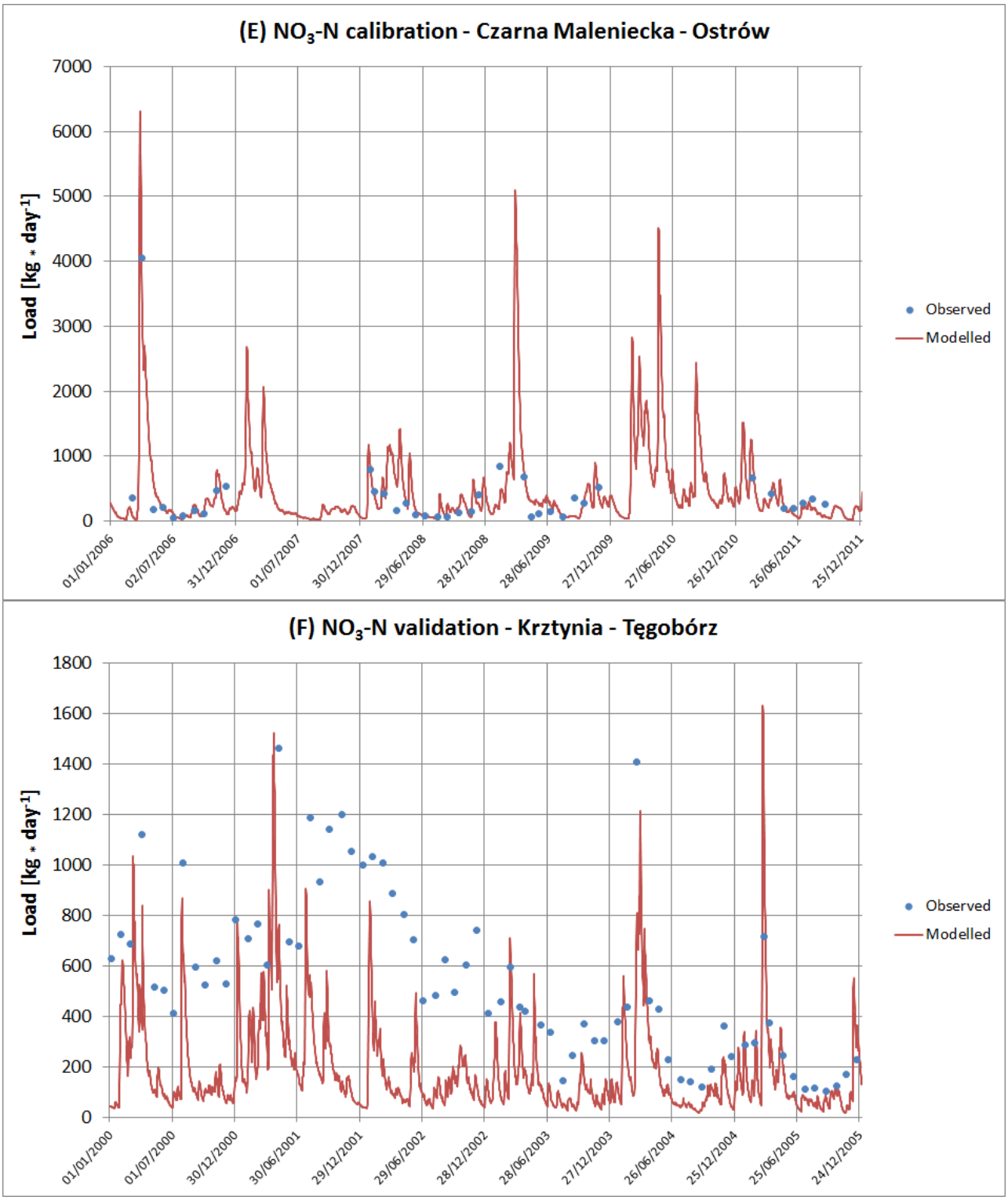
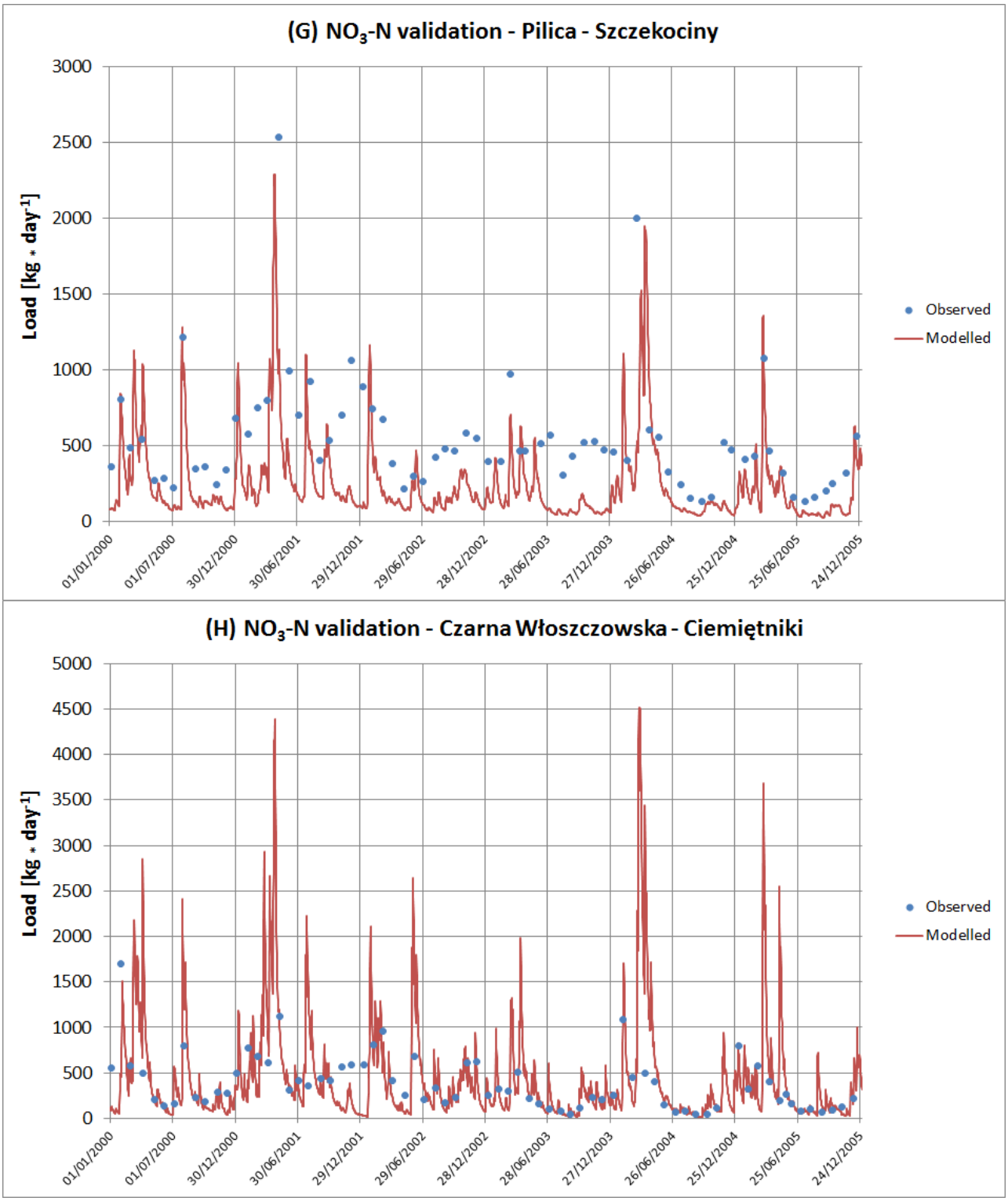


Figure S2. *Cont.*



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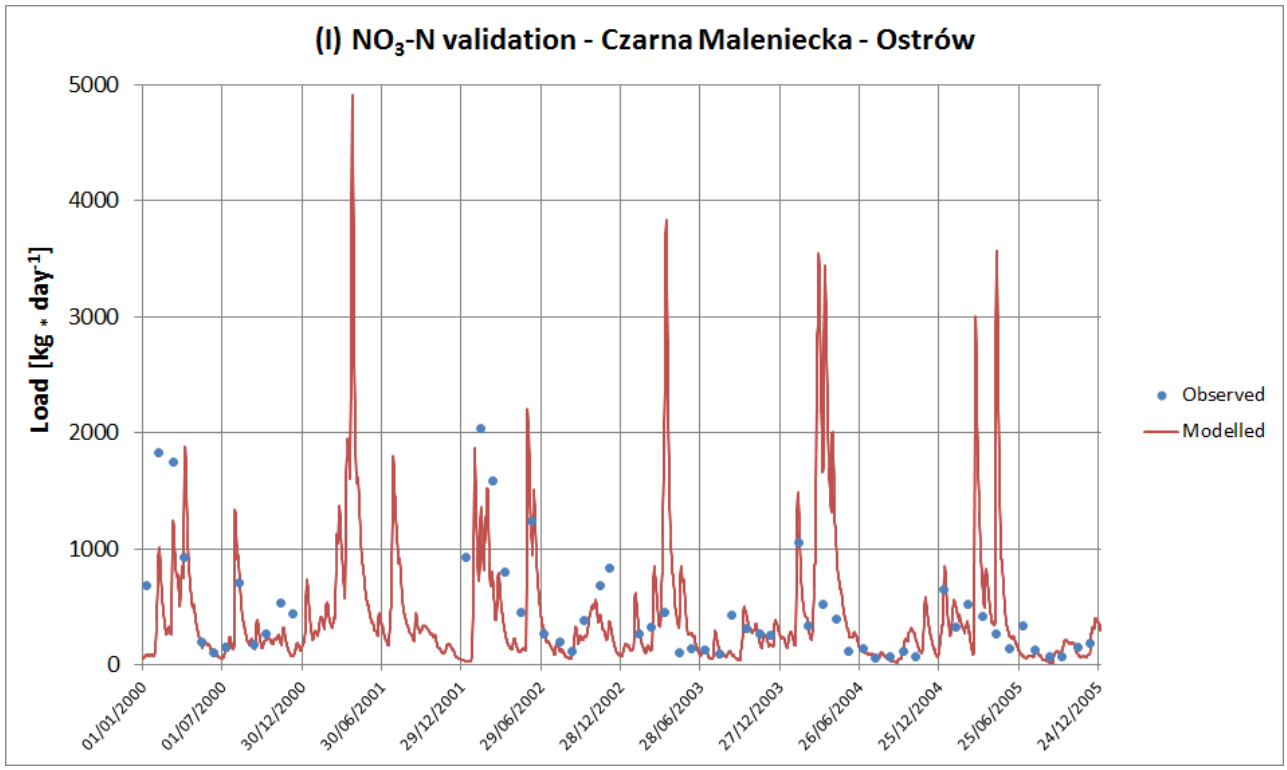


Figure S2. Calibration and validation plots for NO_3-N loads at the SRC gauging stations (plotted values are daily loads calculated for irregular sampling dates, usually one value per month).

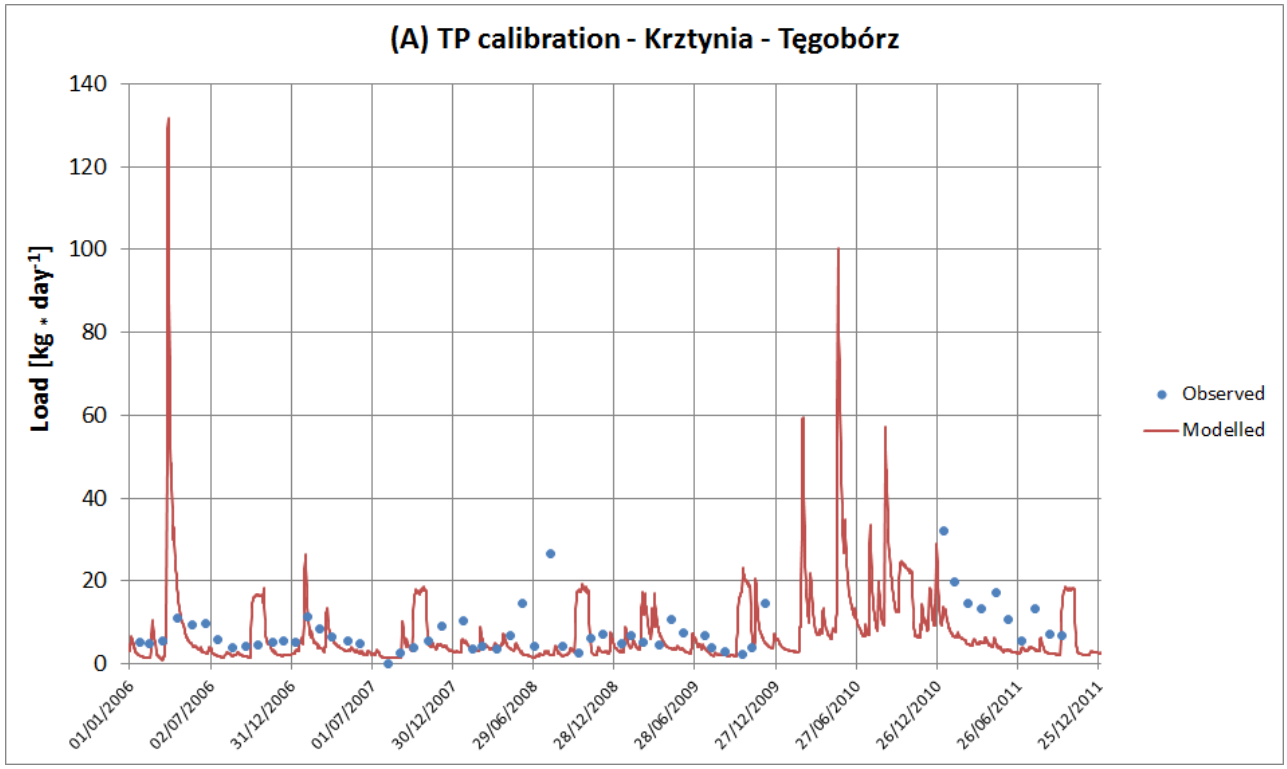
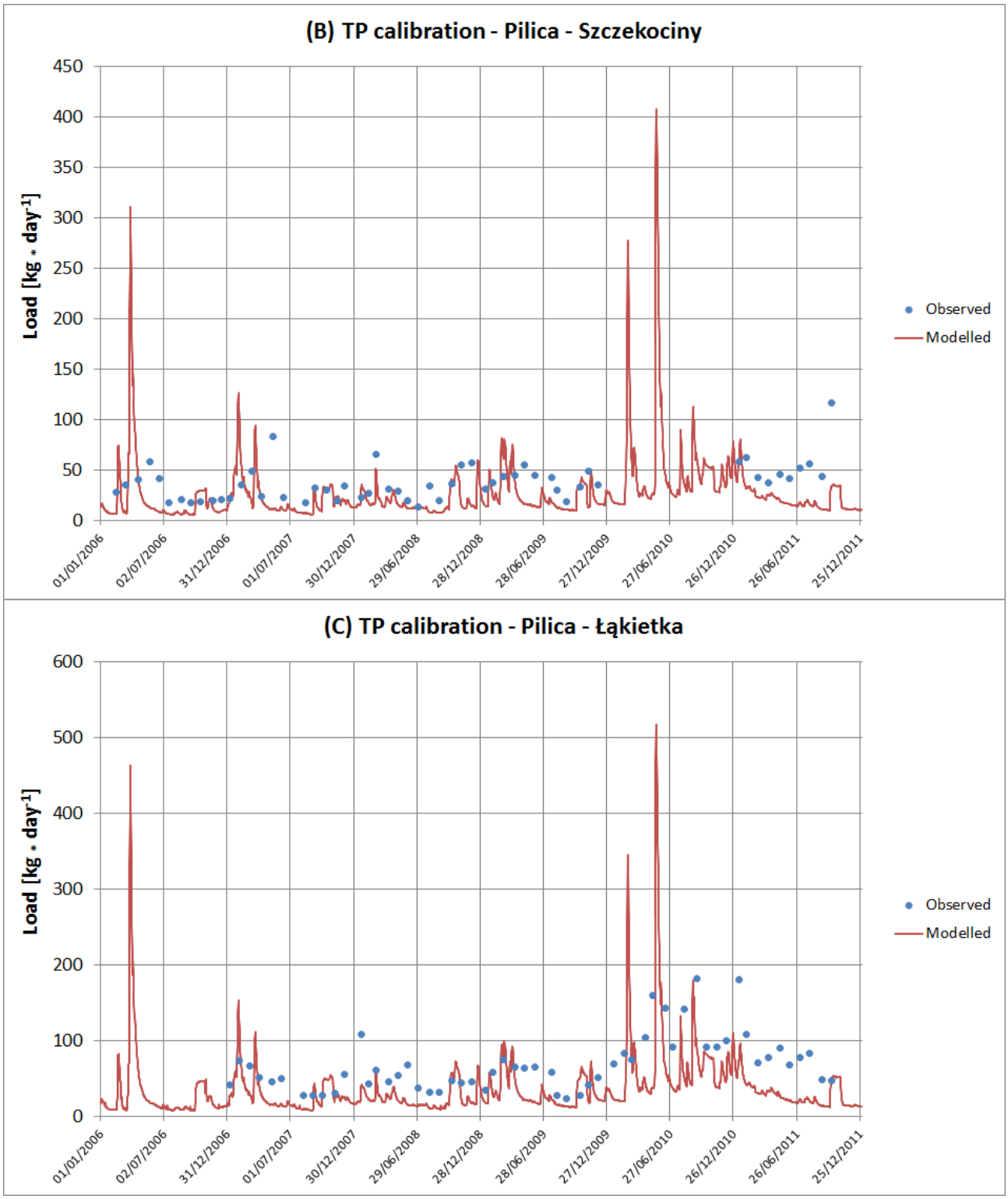


Figure S3. *Cont.*



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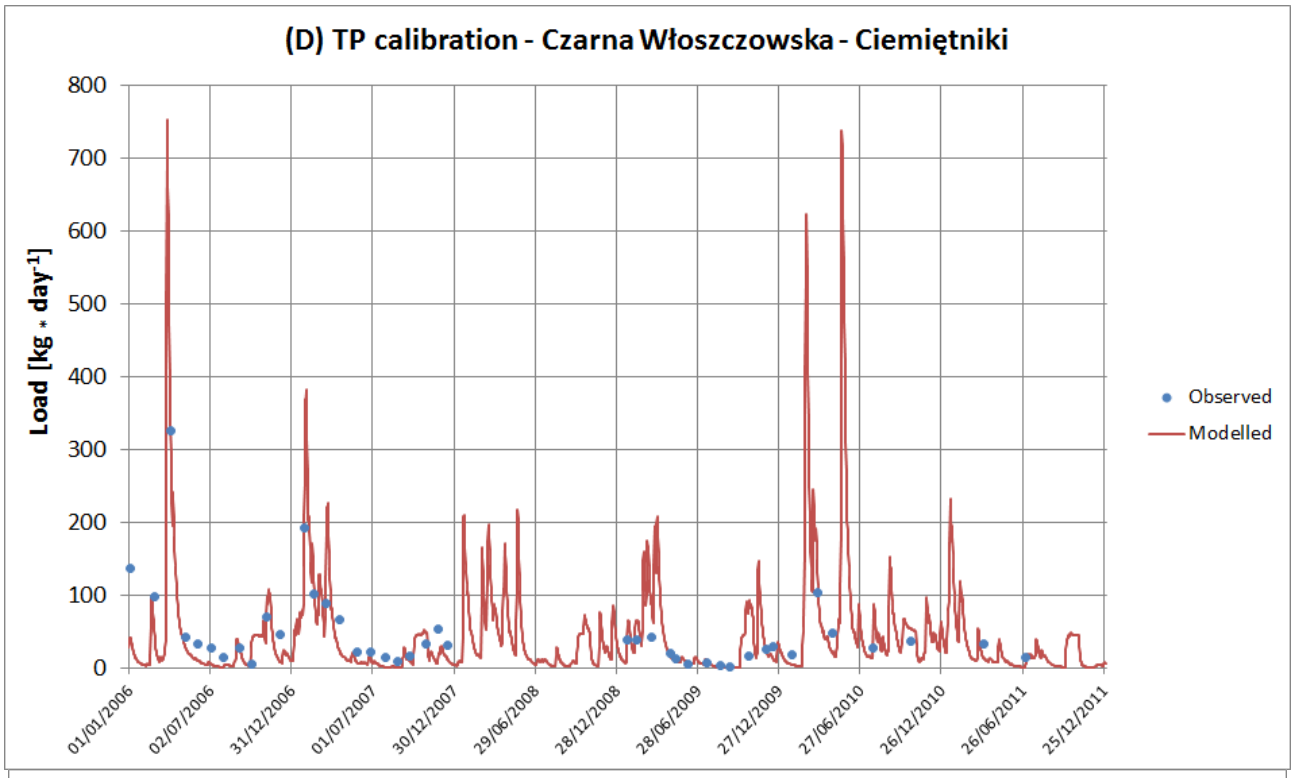

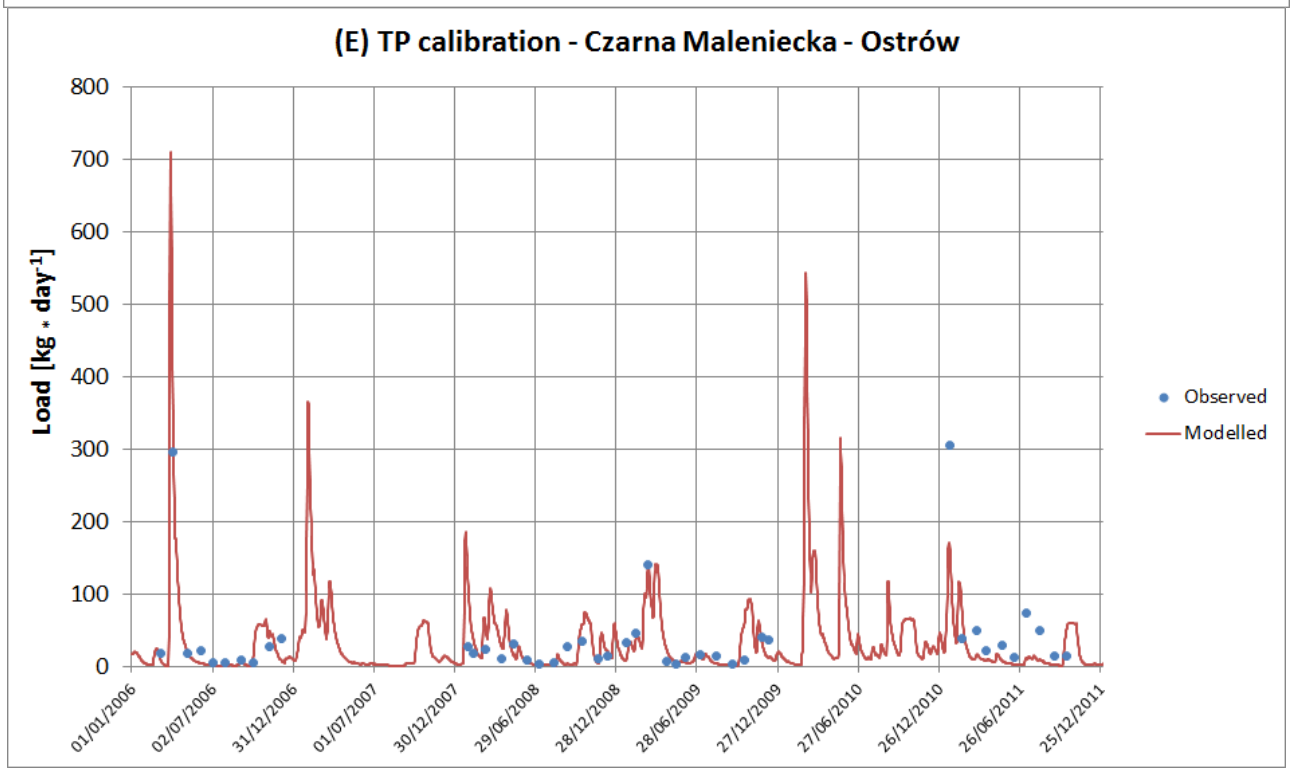

Figure S3. *Cont.*

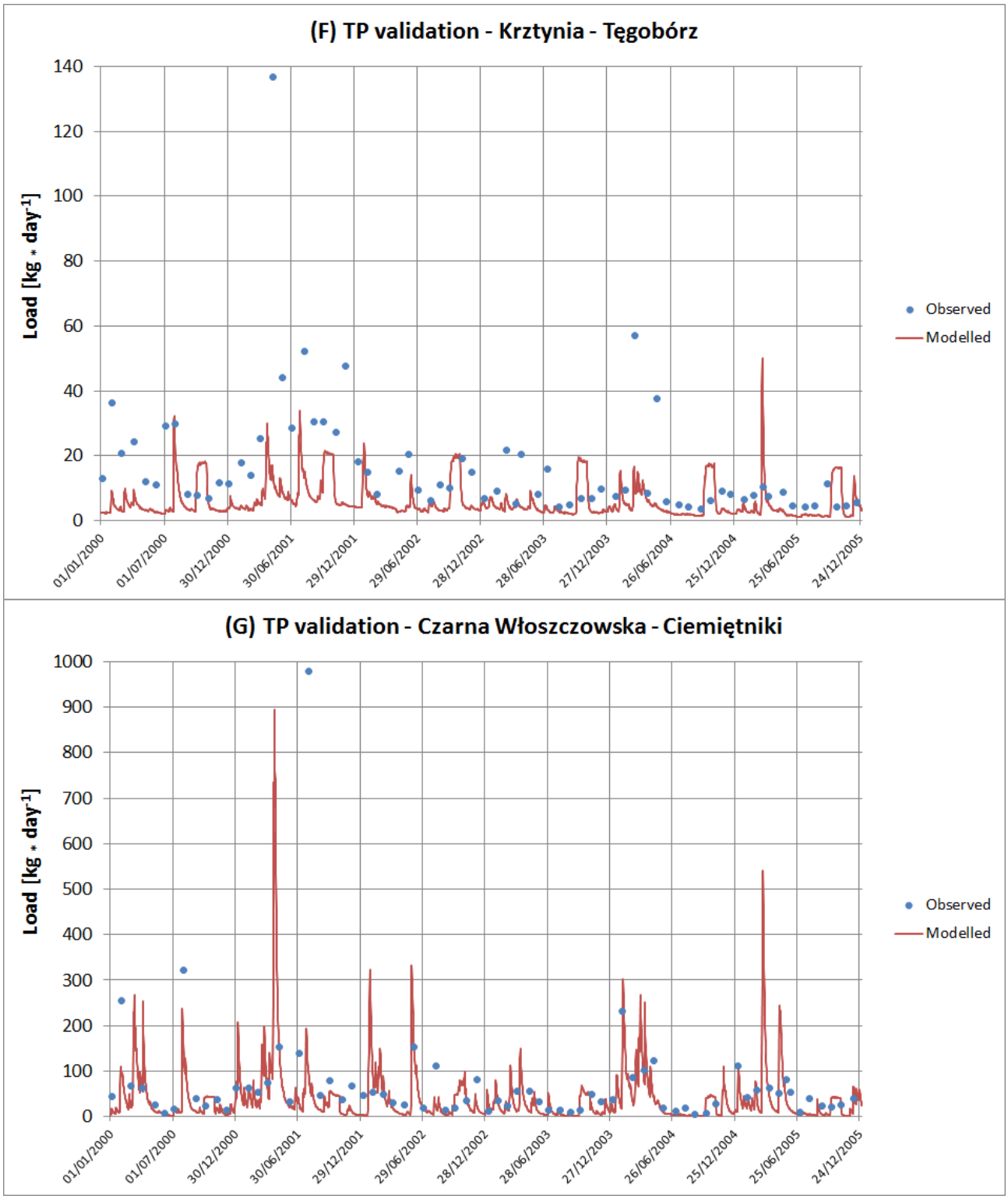

Figure S3. *Cont.*

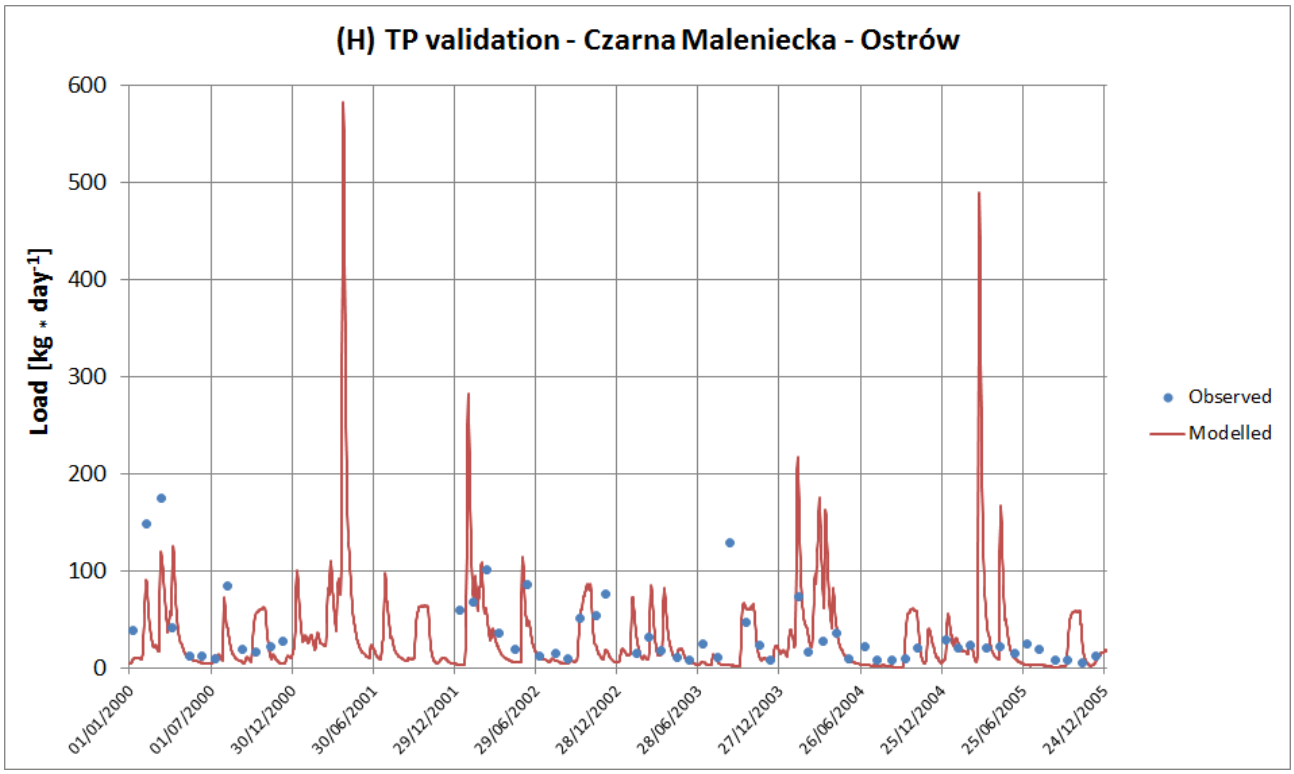

Figure S3. Calibration and validation plots for TP loads at the SRC gauging stations (plotted values are daily loads calculated for irregular sampling dates, usually one value per month).

Table S4. Goodness-of-fit measures for discharge, NO_3-N and TP loads for calibration and validation periods is the SRC gauging stations.

Gauging Station	River	Code	NSE		R^2		PBIAS	
			Cal	Val	Cal	Val	Cal	Val
Discharge								
Sulejów	Pilica	Pil-SUL	0.74	0.69	0.78	0.79	0.05	0.21
Kłudzice	Luciąża	Luc-KLU	0.68	0.61	0.76	0.72	0.13	0.32
Dąbrowa nad Czarną	Czarna Maleniecka	CzM-DAB	0.63	0.69	0.66	0.74	0.2	0.22
Wąsosz Stara Wieś	Krasna	Kra-WSW	0.38	0.52	0.39	0.57	−0.13	−0.02
Przedbórz	Pilica	Pil-PRZ	0.79	0.77	0.79	0.8	0.02	0.1
Januszewice	Czarna Włoszczowska	CzW-JAN	0.67	0.66	0.68	0.68	0.09	0.14
Wąsosz	Pilica	Pil-WAS	0.64	-	0.71	-	0.23	-
Szczekociny	Pilica	Pil-SZC	0.04	0.1	0.61	0.48	0.08	0.17
Bonowice	Żebrówka	Zeb-BON	0.61	0.43	0.73	0.61	0.06	0.31
Bonowice	Krztynia	Krz-BON	0.02	0.35	0.48	0.74	0.03	0.25

Table S4. *Cont.*

Gauging Station	River	Code	NSE		R^2		PBIAS	
			Cal	Val	Cal	Val	Cal	Val
NO3-N loads								
Szczekociny	Pilica	PilSZC	0.3	−0.12	0.63	0.45	0.25	0.54
Ciemiętniki	Czarna Włoszczowska	CzWCIE	0.81	−1.91	0.82	0.11	−0.16	−0.12
Ostrów	Czarna Maleniecka	CzMOST	0.92	0.03	0.92	0.27	0.01	0.08
Przygłów	Luciąża	LucPRZ	0.67	0.18	0.69	0.21	0	0.25
Sulejów	Pilica	PilSUL	0.56	0.3	0.65	0.53	−0.14	0.27
Tęgobórz	Krztynia	KrzTEG	0.09	−0.88	0.69	0.3	0.42	0.64
Łąkietka	Pilica	PilLAK	−0.16	-	0.29	-	0.54	-
TP loads								
Szczekociny	Pilica	PilSZC	−0.99	-	0.09	-	0.44	-
Ciemiętniki	Czarna Włoszczowska	CzWCIE	0.7	0.08	0.79	0.14	0.02	0.40
Ostrów	Czarna Maleniecka	CzMOST	0.64	0.11	0.71	0.31	0.05	0.19
Przygłów	Luciąża	LucPRZ	0.48	−0.05	0.75	0.43	−0.04	0.48
Sulejów	Pilica	PilSUL	0.82	0.1	0.85	0.25	0.02	0.47
Łąkietka	Pilica	PilLAK	−0.55	-	0.31	-	0.49	-
Tęgobórz	Krztynia	KrzTEG	−0.69	−0.21	0.01	0.14	0.31	0.64

Table S5. Goodness-of-fit measures for NO_3-N and TP loads for validation periods before and after adjusting the timing of modelled peaks.

Gauging Station	River	Code	Operation	Statistics before (NSE/R^2/PBIAS)	Statistics after (NSE/R^2/PBIAS)
NO_3-N loads					
Przygłów	Luciąża	LucPRZ	A shift in two peaks by 10 days	0.18/0.21/0.25	0.75/0.75/0.07
Sulejów	Pilica	PilSUL	A shift in two peaks by 9–13 days	0.30/0.53/0.27	0.45/0.63/0.22
Ostrów	Czarna Maleniecka	CzMOST	A shift in two peaks by 7–10 days	0.03/0.27/0.08	0.18/0.40/0.02
TP loads					
Przygłów	Luciąża	LucPRZ	A shift in three peaks by 5–15 days	−0.05/0.43/0.48	0.23/0.59/0.41
Sulejów	Pilica	PilSUL	A shift in three peaks by 2–6 days	0.1/0.25/0.47	0.26/0.52/0.45
Ciemiętniki	Czarna Włoszczowska	CzWCIE	A shift in three peaks by 4–6 days	0.08/0.14/0.40	0.26/0.30/0.36

Table S6. Selected cases with high PBIAS in validation period: comparison of mean discharges and mean loads between calibration and validation periods.

Gauging Station	River	Code	PBIAS Calibration	PBIAS Validation	Mean Discharge Ratio [1]	Mean Load Ratio [2]
			NO_3-N loads			
Szczekociny	Pilica	PilSZC	0.25	0.54	33%	61%
Tęgobórz	Krztynia	KrzTEG	0.42	0.64	64%[3]	119%
Ciemiętniki	Czarna Włoszczowska	CzWCIE	0.02	0.40	13%	44%
			TP loads			
Sulejów	Pilica	PilSUL	0.02	0.47	24%	66%
Tęgobórz	Krztynia	KrzTEG	0.31	0.64	64% [3]	113%

Notes: [1] Ratio between mean discharge in validation period to mean discharge in calibration period; [2] Ratio between mean loads in validation period to mean loads in calibration period; [3] For this gauge only data for 2006–2009 available (2010–2011 missing).