Boreal Peatland Life -project

Effect of restoration and drainage on peatland hydrology: A study of data before and after restoration at 46 sites in Finland

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Abstract

Peatland restorations have been actively done in Finland since the 1970s. The restoration has covered about 1300 hectares of land annually in order to meet the global target of halting the loss of biodiversity and secure ecosystem services. This is for the fact that restoration of drained peatlands is believed to restore back the lost biodiversity or cutoff the loss and naturalize degraded ecosystems. Hence, in this study a total of 46 boreal peatland were investigated, of which 20 are fens, 13 pine mires and 13 spruce mires, with peatland types ranging from nearly ombrotrophic Sphagnum bogs to rich fens. The 27 study sites were drained/restored state and the rest 19 sites were in pristine condition. The pore water chemistry and continuous water table data at all study sites, runoff and stream water chemistry at nine study sties have been monitored since 2008 and are analyzed in this report.

According to our study, drainage has lowered the groundwater level (WT) of mires statistically significantly and also changed the fluctuation dynamics of the WT. Restoration measures have successfully raised the WT to a more natural level (equivalent to the pristine groundwater level) as proven by statistical tests and also restored the natural fluctuation dynamics of the groundwater level. There were differences in the WT rise between mire types. In general, the mean groundwater level rise in nutrient poor spruce mires were larger than the rest of the peatland types considered in this study.

Our study shows also that peatland drainage has changed the chemical properties of pore water as the concentrations of DOC, P_{tot} and N_{tot} were considerably higher in the pore water of the drained sites than in the pristine sites in most cases. According to our study, restoration improved the quality of pore water in most of the mire types and with respect to most of the monitored variables. This positive effect was especially evident and statistically significant for DOC and N_{tot} but concentrations of P_{tot} also showed notable reductions after restoration, suggesting that after restoration pore water quality is getting closer to natural. Generally pH as a water quality parameter and Eutrophic fens were different in this respect: pH was lowered in all mire types and Eutrophic fens showed slight increase in concentrations of DOC, P_{tot} and N_{tot} after restoration.

The chemical quality of pore water and the water flowing from the mires to recipient water courses was compared statistically and gave strongly correlated results, implying that monitoring of pore water quality can be used to estimate the effect of peatland restoration on water quality at receiving water bodies.

Overall, restoration was proven to be an effective tool in restoring the hydrology of mires and subsequently helps bring back the natural ecosystem function (e.g. accumulation of peat) and structure (e.g. mire species) but the monitoring should be continued to get reliable results of the long-term effects of peatland restoration on water quality in the downstream watercourses.

Research questions

During the years 2008-2014, Metsähallitus has thoroughly monitored pristine and drained/restored peatland sites. The monitoring started at 14 sites during 2008 and 2009 and furthermore, the monitoring network included 32 additional sites in 2010 when the Boreal Peatland LIFE project started. All the data collected during 2008-2014 has been well documented and analyzed in this report.

The principal objective of this study was to understand the effect of peatland restoration on water table level and water quality in peatlands and to evaluate whether restoration of peatland has an effect on nutrient loads to the downstream watercourses. As a result, the following three key research questions were formulated:

1. How has drainage affected the water table level and chemical attributes of pore water in peatlands?
2. How does restoration affect the water table level and chemical quality of pore water of peatlands, i.e. has restoration been successful in restoring the natural water table levels and chemical quality of pore water?
3. What are the influences of drainage and restoration of peatlands on runoff and nutrient loads (P, PO_4, N, NH_4, NO_{2+3}, SS, Fe) to downstream watercourses?

Materials and methods

The study comprised 46 thoroughly monitored peatland sites (Fig. 1) of which 13 are pine and spruce mires (with some amount of trees in natural condition) and 20 fens (without trees in natural condition) (Table 1). The nutrient status varied from ombrotrophic to eutrophic (or nutrient poor to nutrient rich), but most of the sites were classified as nutrient poor fens (14 sites). More detailed information about the study sites can be found in Appendix 1.

The study was planned so that each previously drained peatland site had a reference pristine counterpart site, so that effects of drainage will be easily compared with the pristine counterpart, however, two peatland sites (Suo-8 and Suo-49) had no reference counterpart. The reference counterpart sites were located close to drained sites, as a result, the vegetation type and nutrient status of the two sites were similar. This condition enables to produce a valid comparison between drained and their pristine counterparts.

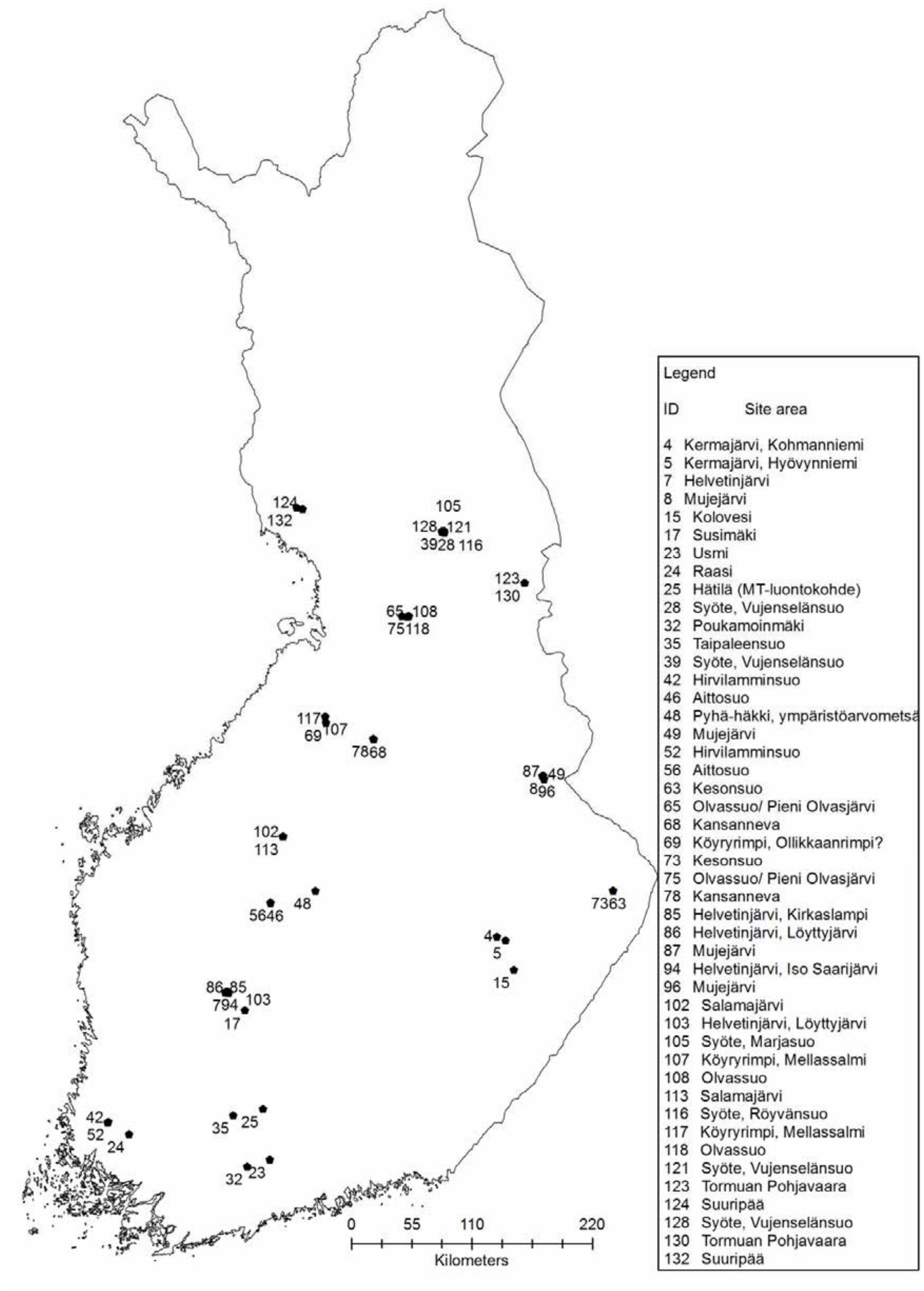

Figure 1. Location of the study sites

Table 1. Classification of the study sites

		Number of sites	**Number of sites with runoff monitoring**
Nutrient status	Poor	23	9
	Intermediate	14	0
	Rich	6	0
Peatland type	Spruce mire	13	2
	Pine mire	13	0
	Fen	20	7
Treatment	Drained/Restored	27	5
	Pristine	19	4

One of the main objectives of restoration was to achieve the water table (WT) in restored sites as close as possible to WT in its pristine counterpart. The rise of WT in restored sites reveals success of restoration. As a result, high resolution (15-30 minute time interval) continuous WT data was collected using Solinst levelogger Gold installed into groundwater pipes (32 mm diameter) in every monitoring site. The Solinst levelogger Gold measures water pressure and atmospheric pressure, hence, atmospheric pressure was collected using Solinst Barologger Gold (in one site Solinst Barologger Edge was used) and was used for compensation of changing atmospheric pressure to obtain accurate water level. In 9 of the study peatland sites, high resolution (15-30 minute interval) continuous runoff was monitored by installing V-notch weirs. Water head in each weir was manually checked circa once a month when water samples for water quality analysis were taken. The manually measured water heads were used to calibrate the runoff measurements. The change in WT of peatlands induced by drainage and restoration was studied by calculating WT differences between drained vs. pristine sites and restored vs. pristine sites. Also data before and after restoration time for individual sites (including pristine counterparts) were compared statistically to see effect of changes in climate. The Wilcoxon signed rank test was used to analyze the changes in WT of drained, restored and pristine counterparts. This analysis helps to understand the effects of drainage and subsequent restoration on WT. Since the drained/restored and pristine counterparts are located nearby, similar weather condition was assumed.

Water quality of peatland pore water was measured from water samples collected 3-4 times during April – November of each year for each monitoring site. The study period varied across the study sites. Furthermore, water quality of runoff water was analyzed by taking a total of 8 to 11 water samples per year. In some of the monitoring sites (see Table 1) both runoff water and pore water were sampled during the same visit. The pore water samples were collected from pipes installed in the peatlands and runoff samples were collected from V-notch weirs located at the outlet of the drained/restored sites and their pristine counterparts. A total of 437 water samples were collected by Metsähallitus during the years 2008-2014 from all monitoring sites. The collected pore water samples were analyzed for total concentrations of phosphorus, nitrogen, DOC, pH electric conductivity (EC) and colour (with wave length of 254 nm). However, the water samples collected from runoff water were analyzed for total phosphorus (P_{tot}), phosphate phosphorus (PO_4-P), total nitrogen (N_{tot}), ammonium (NH_4), nitrite-nitrate (NO_{2+3}), suspended solids (SS), iron (Fe), calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), dissolved organic carbon (DOC), pH, electric conductivity (EC), and color (with wave length of 254 nm).

The effect of drainage and restoration on the pore water quality was studied by comparing the water quality data of pristine sites with the data of drained sites collected before and after restoration. Because drainage of the studied sites has been done decades ago, the chemical and physical properties of the peat have changed considerably since its pristine state. Due to this fact, the effect of restoration on water quality was analyzed using statistical tests to the data before and after restoration from each site – not comparing after restoration situation with pristine counterparts. The statistical tests applied for this task were: 1) Wilcoxon rank sum test; 2) Wilcoxon signed-rank test; and 3) Kruskal-Wallis Test. The Wilcoxon rank sum test is a nonparametric statistical test for two populations when the samples are independent; If X and Y are independent samples with different sample sizes, the test statistic which ranksum returns is the rank sum of the first sample. The Wilcoxon signed rank test is a non-parametric test for two populations when the observations are related or are matched samples. In this case, the test statistic, W, is the sum of the ranks of positive differences between the observations in the two samples (that is, x – y). When the Wilcoxon signed-rank test is used for one repeated sample, then W is the sum of the ranks of positive differences between the observations and the hypothesized median value M0 (which is 0 when you use signrank(x) and m when you use signrank(x,m)). The Kruskal-Wallis is a nonparametric version of classical one-way ANOVA, and an extension of the Wilcoxon rank sum test to more than two groups. It compares the medians of the groups of data in x to determine if the samples come from the same population (or, equivalently, from different populations with the same distribution). This report represents the results obtained from the Kruskal-Wallis test that gave clear differences.

The effect of drainage and restoration on nutrient loading to downstream watercourses was evaluated by comparing element loads of the samples collected from the v-notch weirs from situations before and after restoration to that of the pristine counterparts. In order to minimize a misleading conclusion due to probable differences between counterparts, additional comparison within drained/restored sites before and after restoration was done. Based on the loading at pristine counterparts, the increase calculations were adjusted to take into account the differences observed in element load between the counterparts and situation before-after restoration operation at study sites.

The increase I was calculated as in equation (1)

$$\mathrm{I} = \frac{(Y2 \cdot Y\% + Y2) - Y1}{Y2 \cdot Y\% + Y2} \cdot 100\% \qquad (1)$$

where Y_2 is measured load after restoration; $Y_{\%}$ is perceptual difference of load between the sites before restoration; and Y_1 measured load before restoration.

Results

Effect of drainage and restoration on WT

Drainage has substantially lowered WT in studied peatlands as can be seen in Figures 2 and 3. The groundwater level difference between pristine and drained sites (data before restoration in the figures) was systematically below zero indicating WT level of drained sites to be below WT of pristine sites (Fig. 2). Also Wilcoxon rank test for the WT data proved that drainage has lowered significantly WT ($\text{median}_{\text{pristine}}$ = -12.25 cm, $\text{median}_{\text{before restoration}}$ = -29.74 cm, N = 6700, Z = 63.60, p = 0.000).

Restoration has noticeably elevated WT as the groundwater difference between pristine and restored sites was systematically above zero (Fig. 2) According to Wilcoxon rank test, median values of WT difference before and after restoration significantly differed (Z = -26.41, N = 537, p < 0.01). The median WT difference before restoration was -19.86 cm whereas after restoration it was 2.02 cm. The negative value before restoration means that the WT of drained sites were lower than the WT of pristine sites. This was also confirmed by comparing the median WT values of pristine sites and restored sites: Wilcoxon rank test showed no any significant differences in the data sets specifying that after restoration WT (median = -7.84 cm) was at same level than WT of the pristine sites (median = -10.29 cm). Overall, the WT results indicate that the restoration had gained the required target by replenishing the WT close to natural level.

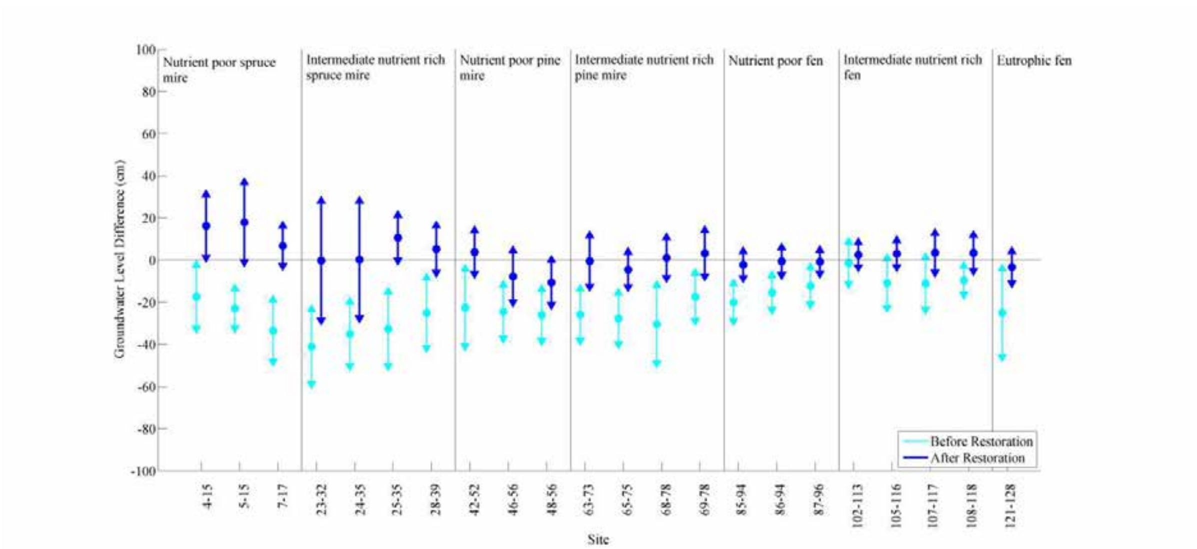

Figure 2. Mean groundwater level difference between drained/restored and pristine sites before and after peatland restoration. Arrows show standard deviation of the data. The data has been classified according to peatland type.

Restoration by filling in/blocking ditches has clearly raised the groundwater level in 15 peatland sites, especially in the spruce and pine mires. In 11 of the study sites, almost exclusively fens, the raise in groundwater level was smaller (Figures in the Appendix 2). The mean WT elevations of the study sites with standard deviation of the data before and after restoration along with their pristine counterparts are shown in Fig. 3. In nutrient poor spruce mires, the mean groundwater increase was clearly larger than the mean groundwater increase in the rest of the peatland types. The WT rise was small in some of the study sites, but in these sites mean WT were already close to its pristine counterparts. The WT in two of the study sites was higher than its pristine counterpart immediately after ditch blocking but later reached to the level of its pristine counterpart site in the second year.

In addition to the rise in the median WT level, restoration triggered the recovery of natural fluctuation of WT. This can be referred to in appendix 2 of the WT time series of all studied sites where the periodic fluctuation of the WT data in restored sites was smaller and much closer to that seen in the pristine counterparts when compared to the WT periodic fluctuation observed before restoration.

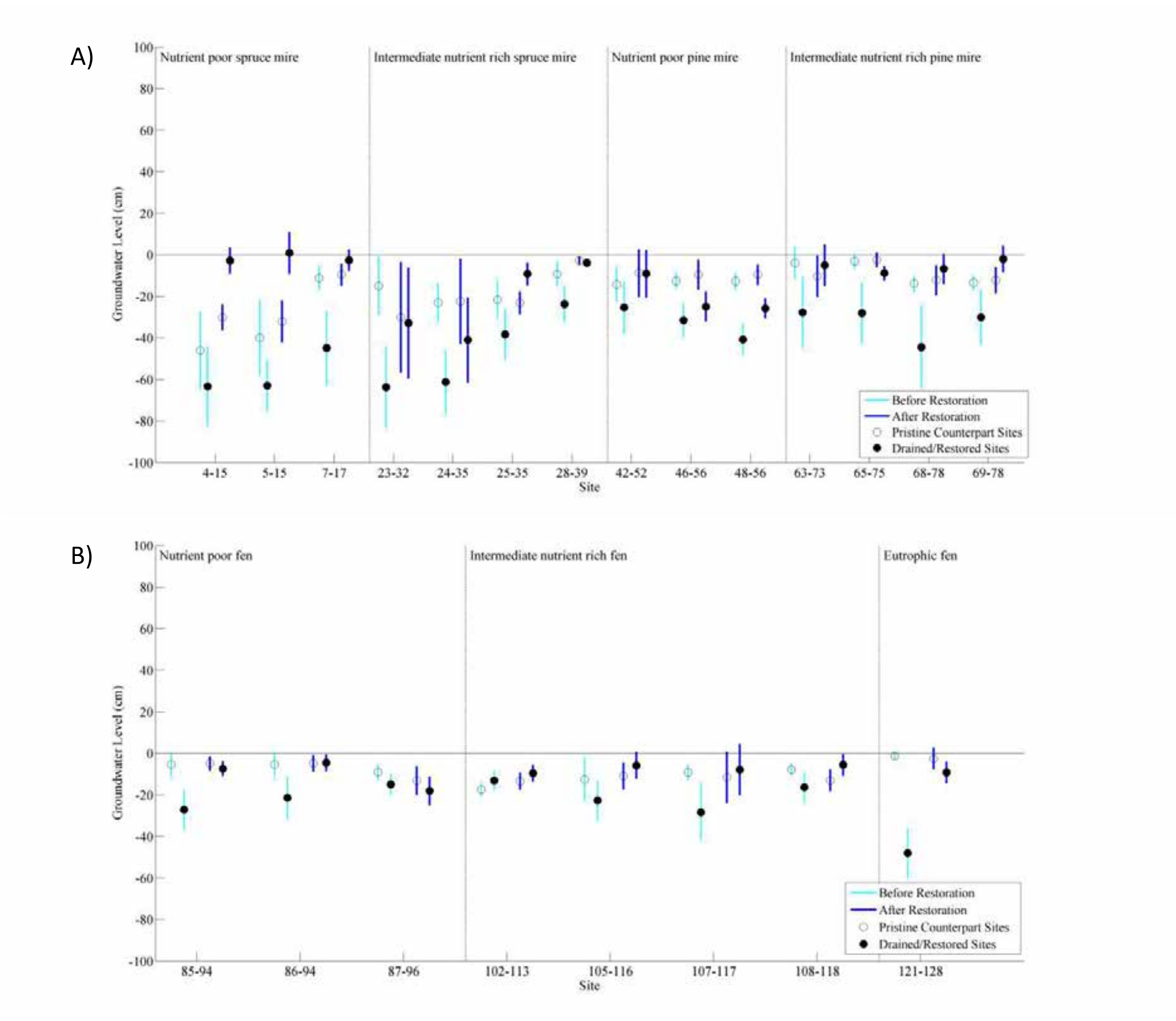

Figure 3. Mean groundwater level before and after restoration in drained/restored spruce mires and pine mires (A) and fens (B) with their pristine counterparts classified based on nutrient status of peatland. The line shows standard deviation of the data.

Effect of drainage and restoration on pore water quality

Drainage has changed the water quality in peatland areas. This was clearly seen from the comparison made between collected pore water data from drained sites (before restoration) and pristine counterparts. Figure 4 shows total P concentration along with WT data in drained/restored site Suo-7 and its pristine counterpart site Suo-17. Generally, DOC, P_{tot} and N_{tot} concentrations were larger in the drained sites than in their pristine counterparts (Fig. 5 and 6). However, this was not very clear for P_{tot} concentration because the ranges of before restoration dataset and pristine dataset were partly on top of each other (Fig. 5C). Based on the Wilcoxon test, only pH of measured water quality parameters in drained sites were similar (not statistical significant differences were observed by the test) with the value of pristine sites within the peatland type of spruce and pine mires and within the nutrient status of eutrophic and intermediated nutrient rich sites. Addition to pH, pore water P_{tot} concentration was observed to be close to natural values in spruce mires. The results indicate that after drainage spruce mires were the most stabilized.

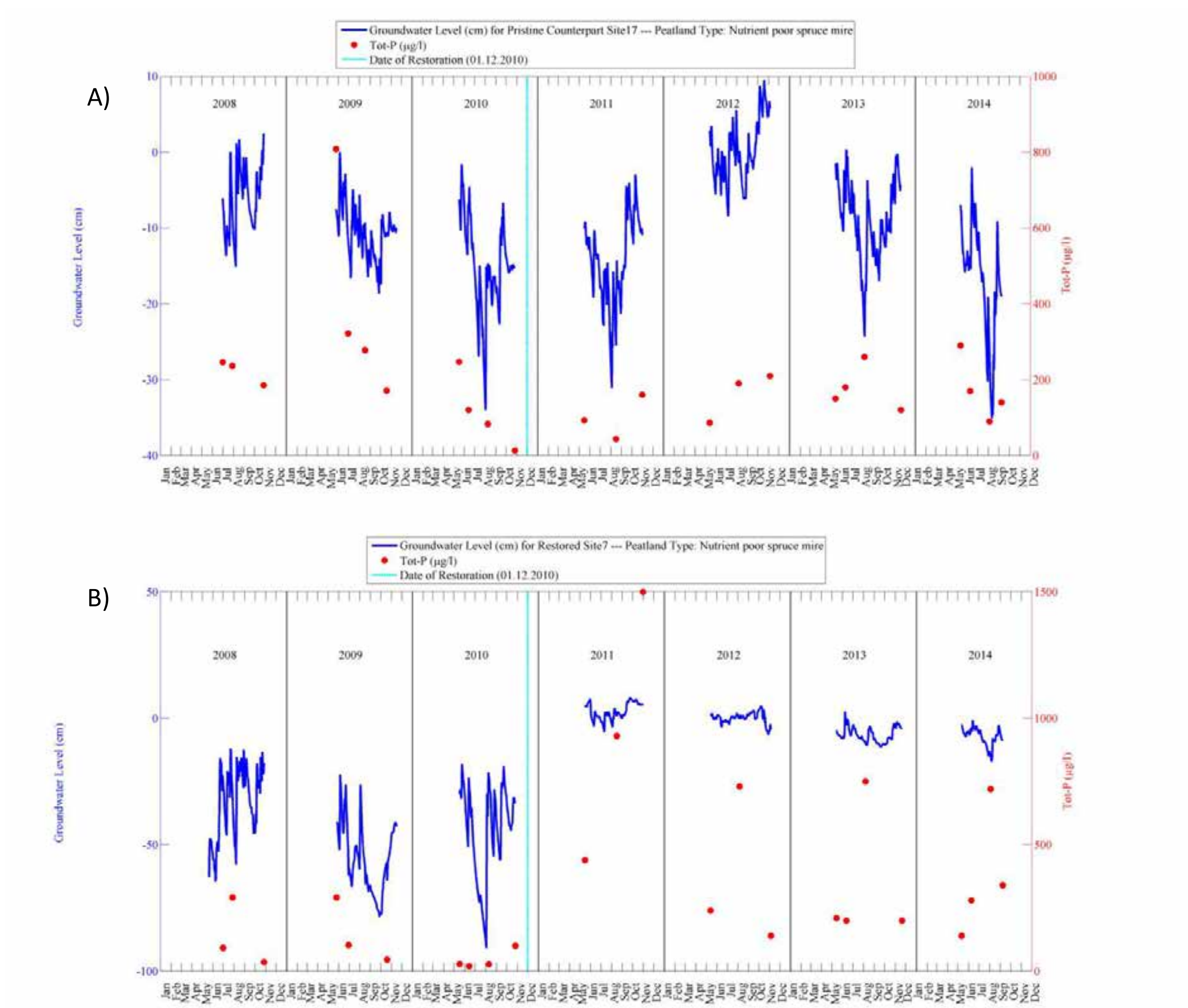

Figure 4. The total phosphorus concentration in pore water samples and groundwater level (WT) at the pristine site Suo-17 (A) and its drained/restored counterpart Suo-7 (B). The light blue line shows the time when Suo-7 was restored.

A)

B)

C)

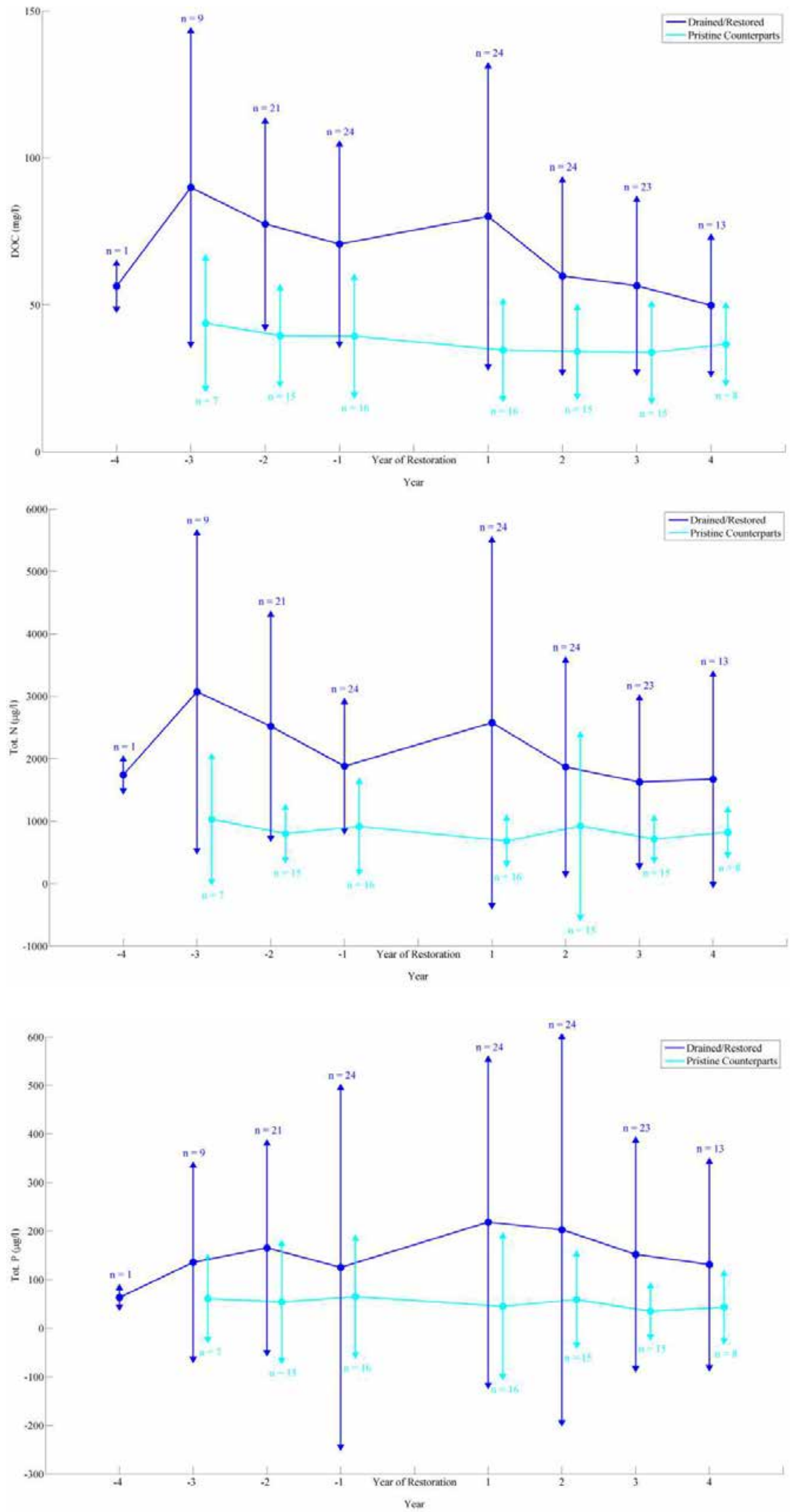

Figure 5. Mean DOC (A), N_{tot} (B) and P_{tot} (C) concentrations in pristine and drained/restored mires (nutrient poor and intermediate nutrient rich pine and spruce mires and fens). n is number of sites and arrows indicate standard deviation of the data.

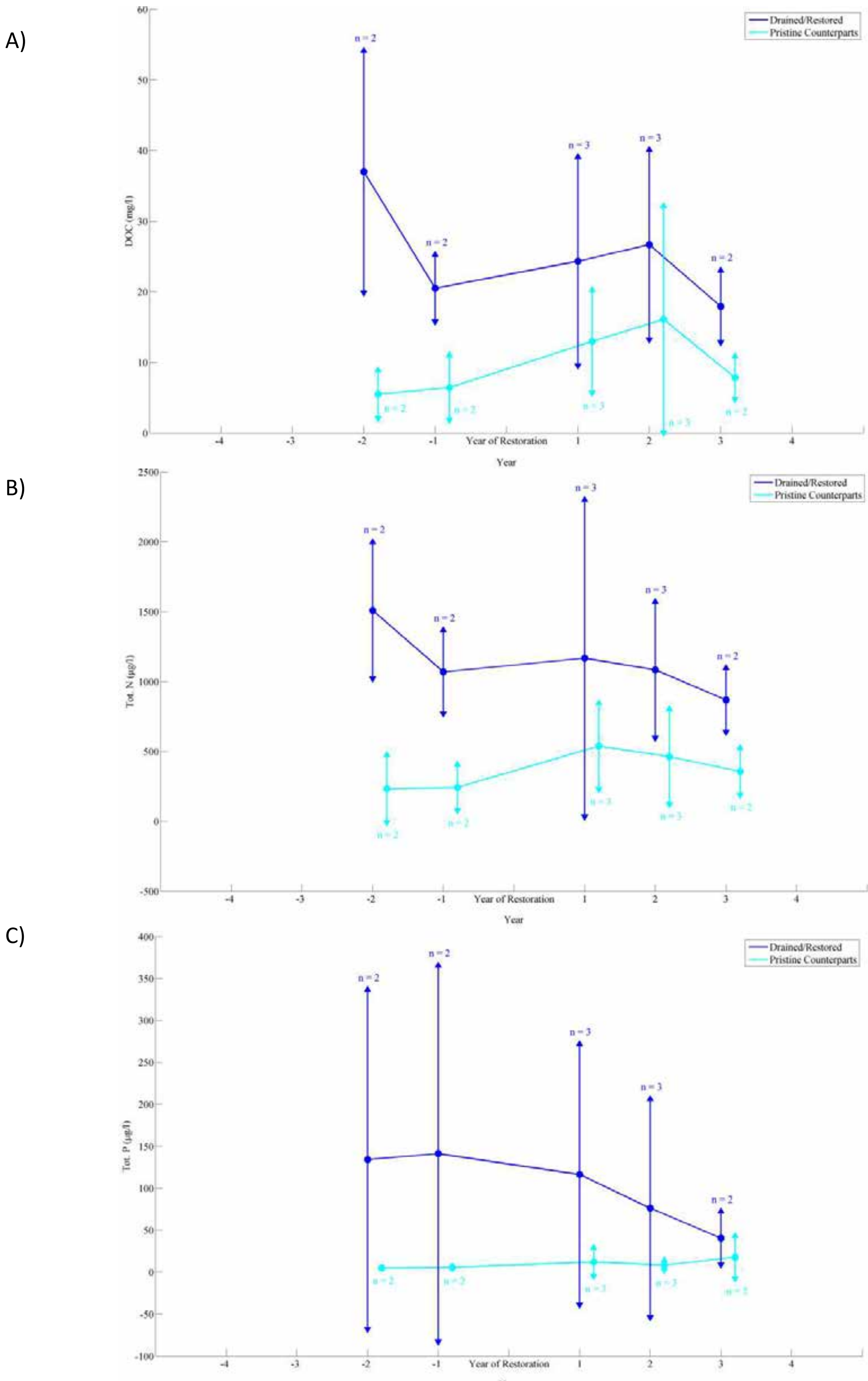

Figure 6. Mean DOC (A), N_{tot} (B) and P_{tot} (C) concentrations in pristine and drained/restored eutrophic fens. n is number of sites and arrows indicate standard deviation of the data.

Based on the Wilcoxon test, the effect of restoration on the pore water quality was observed clearly (Table 2). The largest concentration changes were recorded in N_{tot} and DOC. This was seen as well when data was divided based on peatland type and nutrient status (except eutrophic sites). Although the difference in P_{tot} before and after restoration was not statistically significant in any groups, the median concentration after restoration (28 µg/l) was lower than the median concentration (39 µg/l) before restoration. This was also observed in the data divided based on peatland type. Because of low number of samples, no any remarkable changes were found within eutrophic sites where generally phosphorus, nitrogen and DOC concentrations were larger after restoration.

The ultimate goal of restoration is to achieve natural water quality level in previously drained peatlands. This takes time which can be seen in the pore water quality data of the studied peatlands: After restoration the water quality has recovered closer to natural state (pristine counterparts) but not reached the natural levels (Table 2). Also Wilcoxon tests proved that after restoration water quality differed from pristine sites significantly indicating that sites have not recovered their natural state after restoration. Only pH in pine mires was similar with pH in pristine sites after restoration (Wilcoxon rank test showed not statistical difference between data sets). The detail statistical analysis for before and after restoration data sets and for all tested groups and parameters are presented in Table 2.

Table 2. Results from Wilcoxon rank test for the water quality data of pore water. Dark grey color indicates statistically significant results ($p < 0.05$). N is number of samples. The median values of water quality parameters in pristine sites are showed as a reference value with light grey background.

	ALL DATA						**FENS**					
	pH	EC (µS/m)	P_{tot} (µg/l)	N_{tot} (µg/l)	UV-ABS	DOC (mg/l)	pH	EC (µS/m)	P_{tot} (µg/l)	N_{tot} (µg/l)	UV-ABS	DOC (mg/l)
Pristine median	4.5	3.8	14	649	131	32.7	4.7	3.4	9	530	103.89	26
N_{Before}	307	309	310	311	313	316	180	184	182	184	185	185
N_{After}	635	635	632	627	630	641	305	306	307	306	307	307
$Median_{Before}$	4.4	4.5	38.5	1168	210	52.3	4.4	4.1	29	1022	220	50.1
$Median_{After}$	4.3	4.4	28	890	185	40	4.2	4	20	720	182	41
Z	1.58	0.02	1.58	4.41	2.1	5.95	3.54	-0.19	1.68	3.94	2.54	4.39
p	0.115	0.981	0.115	0.000	0.036	0.000	0.000	0.852	0.092	0.000	0.011	0.000

	EUTROPHIC SITES						**PINE MIRES**					
	pH	EC (µS/m)	P_{tot} (µg/l)	N_{tot} (µg/l)	UV-ABS	DOC (mg/l)	pH	EC (µS/m)	P_{tot} (µg/l)	N_{tot} (µg/l)	UV-ABS	DOC (mg/l)
Pristine median	6.5	6.1	5.75	385	31.8	9.15	4.2	3.9	13	660	184	43
N_{Before}	19	19	18	18	18	19	101	101	99	101	102	102
N_{After}	60	60	60	60	60	60	187	187	186	186	186	187
$Median_{Before}$	6.7	5.7	6.5	550	35.2	13	4.3	4.9	63	1500	249	63.05
$Median_{After}$	6.35	6	14	640	65.7	14	4.1	5.1	37.5	1200	254	57
Z	2.42	-0.31	-1.37	-0.7	-2.42	-0.91	3.88	-0.99	0.63	1.93	-0.51	2.39
p	0.016	0.757	0.171	0.484	0.016	0.365	0.000	0.323	0.526	0.054	0.613	0.017

	INTERMEDIATE NUTRIENT RICH SITES						**SPRUCE MIRES**					
	pH	EC (µS/m)	P_{tot} (µg/l)	N_{tot} (µg/l)	UV-ABS	DOC (mg/l)	pH	EC (µS/m)	P_{tot} (µg/l)	N_{tot} (µg/l)	UV-ABS	DOC (mg/l)
Pristine median	4.7	3.8	21	720	169	36	5.2	4	63	1000	149	32.45
N_{Before}	97	95	95	96	97	99	69	67	71	70	71	73
N_{After}	194	193	191	189	190	195	181	180	177	173	175	185
$Median_{Before}$	4.8	4.5	69	1770	260	60.8	4.8	5	92	1770	213	55.8
$Median_{After}$	4.7	4.2	62	1200	221	44	4.6	4.4	86	1200	195	40
Z	0.96	1.17	0.3	2.85	1.22	4.47	0.69	2.54	1.24	3.27	0.89	4.07
p	0.338	0.242	0.763	0.004	0.222	0.000	0.488	0.011	0.216	0.001	0.374	0.000

	NUTRIENT POOR SITES					
	pH	EC (µS/m)	P_{tot} (µg/l)	N_{tot} (µg/l)	UV-ABS	DOC (mg/l)
Pristine median	4.3	3.6	13	660	129.905	33
N_{Before}	191	195	197	197	198	198
N_{After}	381	382	381	378	380	386
$Median_{Before}$	4.2	4.5	32	1070	209	51.45
$Median_{After}$	4.1	4.45	26	840	185	41.35
Z	2.53	-0.52	1.5	3.66	1.69	4
p	0.012	0.6	0.134	0.000	0.091	0.000

Pore-water quality vs. runoff water quality

Water quality analyzed from samples taken from pipes (the suo data representing pore water in the sites) correlated significantly with samples taken from V-notch weirs (the pato data represents runoff from the sites) (Figs. 7 and 8). The correlation was larger than 0.40 for all analyzed parameters and it was slightly larger after restoration (for e.g. N_{tot} and UV) than before restoration. In P_{tot} data, the correlation was larger before ($r = 0.75$, $p = 0.00$) than after restoration ($r = 0.58$, $p = 0.00$). The lower correlation between P_{tot} concentrations before and after restoration might be due to restoration activities in the sites resulting larger phosphorous concentrations in runoff water than the pore water quality. Generally, from the analyses, it can be recommended that pore water samples can be used to monitor and estimate the effect of drainage/restoration on water quality variations. This helps to save unnecessary costs to weir building for runoff water, saves enormous time and energy and furthermore, avoids extra analysis costs. Hence, the pore water samples can easily be collected and give reliable information with regard to water quality changes driven by restoration. However, in the data set collected after restoration, there was higher variation and few out layers in the plots describing relationships between runoff and pore water samples (Fig. 7), especially for N_{tot} and P_{tot}, which increase uncertainty of the method. Therefore, the pore water samples collected in a small area of a given site are not sufficient to estimate accurate nutrient loads unless the data sampling considers representative water sampling locations over the catchment.

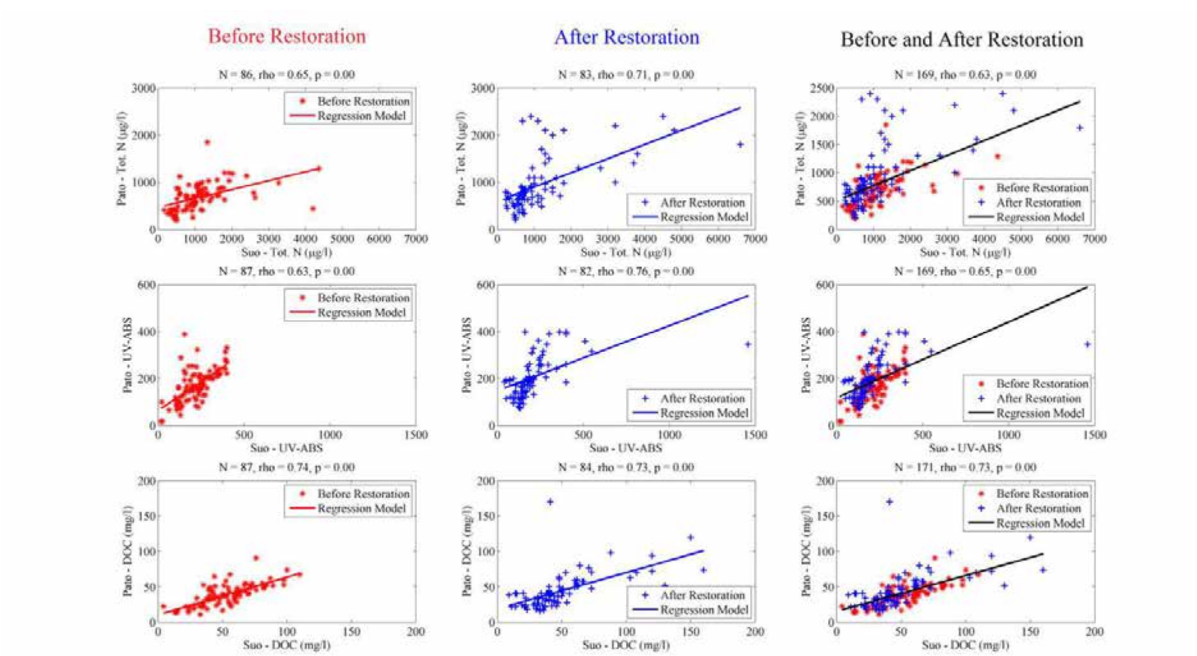

Figure 7. Correlation analysis for N_{tot}, UV-ABS and DOC in pore-water (suo-data) and runoff water (pato-data) in all runoff monitoring sites.

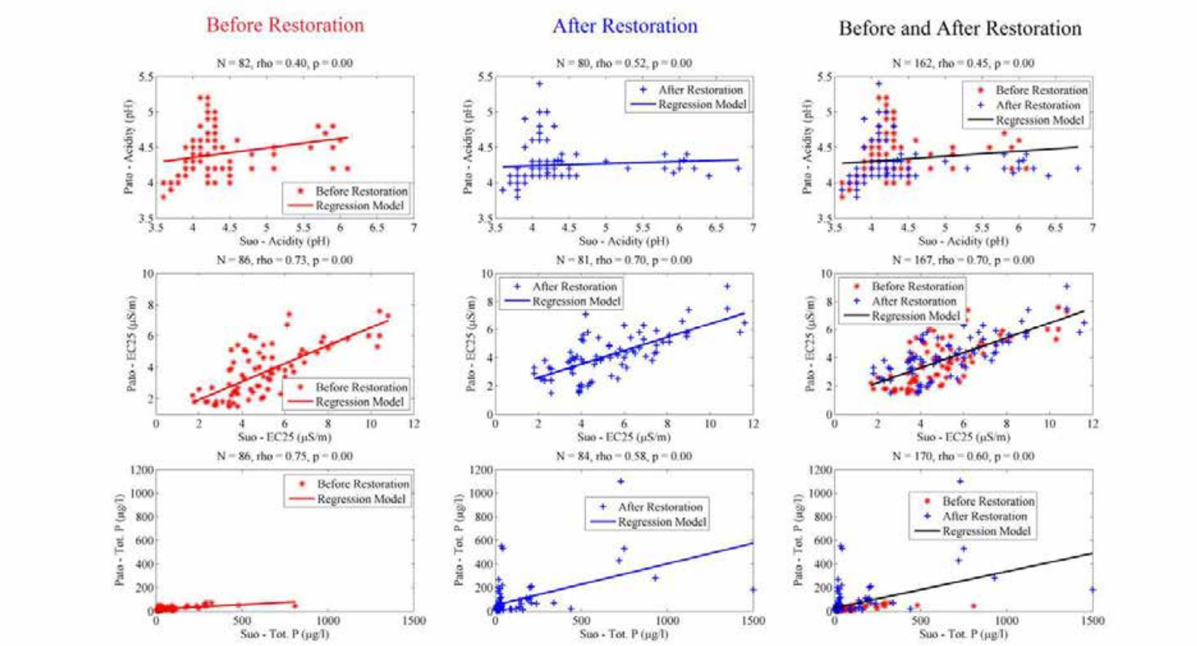

Figure 8. Correlation analysis for acidity (pH), electric conductivity (EC25) and P_{tot}, in pore-water (suo-data) and runoff (pato-data) in all sites runoff monitoring sites.

Effect of peatland drainage and restoration on runoff

Runoff from drained peatlands (before restoration) was generally similar or slightly lower than its pristine counterpart. However, in one of the study sites (Suo-7), runoff was significantly larger than its pristine counterpart during the years before restoration (Table 3, Appendix 3). Mean daily runoff was 0.76 mm/d from the drained peatland (Suo-7) and only 0.24 mm/d from its pristine counterpart (Suo-17). Based on the available data, drainage has not significantly changed the mean runoff from the studied sites.

The measures of central tendency and dispersion for collected runoff data during the years 2008-2014 are shown in Table 3. The mean runoff showed an increase of 17 % - 80 % in the study sites. This was proved by Wilcoxon rank test, which gave an increase of the median runoff in Suo-7 and Suo-86 drained peatlands after restoration (Suo-7: Z = -11.4, p = 0.00000, Suo-86: Z = -9.2, p = 0.00000). However, statistically significant decrease (Z = 3.6, p = 0.000324) of the median runoff obtained in Suo-105 study site. Furthermore, in the study site Suo-85, the mean runoff decreased from 0.67 mm/d to 0.54 mm/d before and after restoration, respectively, however, the difference was not statistically significant. In the study site Suo 103/1, the mean runoff was nearly equal before (0.70 mm/d) and after restoration (0.65 mm/d) and the Wilcoxon rank test revealed no statistical difference between mean runoff before and after restoration. This inconsistency could be due to the fact that there might take some time until the hydrology of restored peatland recovers. However, the lack of precipitation data on the study sites prevented more discussion on the matter.

Table 3. Mean runoff (mm/d) of the studied sites from 2008 to 2014. Bolded values in light green represent years after restoration.

Site	Year	2008	2009	2010	2011	2012	2013	2014
7	N	159	197	163	**189**	**197**	**191**	**127**
	Mean	1.48	0.21	0.59	**1.93**	**1.95**	**0.74**	**0.84**
	SD	1.88	0.44	1.39	**2.16**	**2.63**	**1.12**	**1.12**
	Min	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**
	Max	10.99	2.74	10.39	**12.39**	**15.33**	**10.08**	**7.87**
17	N	120	197	169	196	188	213	127
	Mean	0.48	0.13	0.13	0.27	0.49	0.08	0.06
	SD	0.53	0.25	0.21	0.34	0.44	0.15	0.14
	Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Max	2.72	1.20	1.26	1.56	2.33	1.02	1.13
85	N	160	197	169	**189**	**197**	**191**	**127**
	Mean	1.12	0.23	0.66	**0.58**	**0.81**	**0.32**	**0.44**
	SD	1.25	0.27	1.04	**0.57**	**1.08**	**0.56**	**0.59**
	Min	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**
	Max	7.21	1.56	6.49	**3.16**	**5.74**	**2.77**	**3.82**
86	N	181	197	163	**189**	**197**	**213**	**127**
	Mean	0.96	0.08	0.48	**0.46**	**1.13**	**0.57**	**0.54**
	SD	1.39	0.16	0.94	**0.87**	**1.83**	**0.97**	**0.76**
	Min	0.00	0.00	0.00	**0.00**	**0.01**	**0.00**	**0.00**
	Max	7.23	1.00	7.02	**5.69**	**11.93**	**9.55**	**5.59**
94	N	120	197	169	189	197	213	127
	Mean	1.51	0.14	0.37	0.68	0.88	0.79	0.66
	SD	1.10	0.15	0.53	0.68	1.08	0.79	0.72
	Min	0.20	0.00	0.00	0.00	0.01	0.00	0.00
	Max	5.38	0.79	3.32	4.01	6.40	4.79	4.92
105	N		105	218	188	**167**	**180**	**118**
	Mean		0.35	1.59	1.22	**2.57**	**1.00**	**1.26**
	SD		0.31	3.57	1.25	**5.32**	**1.96**	**2.50**
	Min		0.01	0.04	0.03	**0.04**	**0.01**	**0.00**
	Max		1.45	35.64	7.47	**34.85**	**10.35**	**12.75**
116	N		104	218	188	167	180	118
	Mean		0.58	1.61	2.30	2.25	1.17	1.35
	SD		0.44	3.62	2.84	4.14	2.12	2.99
	Min		0.10	0.15	0.00	0.13	0.08	0.05
	Max		2.18	28.39	13.88	26.89	13.28	18.17
103/1	N	180	197	184	189	**188**	**191**	**127**
	Mean	1.13	0.16	0.69	0.83	**0.88**	**0.49**	**0.59**
	SD	1.85	0.21	1.30	1.67	**1.16**	**1.25**	**1.03**
	Min	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**
	Max	9.85	1.21	11.78	10.83	**6.08**	**12.54**	**7.05**
103/2	N	180	197	184	189	197	213	127
	Mean	1.13	0.15	0.63	0.76	1.48	0.85	0.91
	SD	1.79	0.23	1.09	1.57	2.71	1.99	1.62
	Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Max	10.33	1.35	8.61	10.33	17.11	14.40	12.15

N = number of days; Mean = mean value of data; SD = standard deviation; Min =minimum value of the data; Max = maximum value of data

Effect of peatland restoration on nutrient loading to downstream watercourses

The effect of restoration on nutrient concentrations of stream water were studied in 5 restored sites (weir). Before and after restoration conditions and nutrient concentrations were compared within sites and against their pristine counterparts. Significant variations in nutrient concentrations were observed between study sites after restoration and between study years. Generally, total phosphorus (P_{tot}), phosphate (PO_4-P), total nitrogen (N_{tot}), ammonium (NH_4-N), iron (Fe) and potassium (K) concentrations gave larger values after restoration (refer to Fig. 9 and appendixes 3-7). Larger values were especially observed during the first year of restoration. The aforementioned result is in agreement with previous findings of restored peatlands, and reflect changing conditions for biogeochemical processes at peat after elevated WT. Especially phosphorus and iron are sensitive for changes in anoxic conditions, whereas elevated nitrogen concentrations indicate increased microbial and decomposition activity in peat layers due to increased WT. Restoration did not show any particular increase in concentrations of dissolved organic carbon (DOC), calcium (Ca), electrical conductivity (EC), magnesium (Mg), sodium (Na), pH-level, solids and nitrite-nitrate ($NO_{2\text{-}3}$-N) in samples collected from runoff waters. However, in order to understand the effect of restoration in all sites thoroughly, further analysis on differences in hydrological years before and after restoration operation need to be done.

Generally, drained sites produced higher loading when compared to pristine sites, however there was some variation in the dataset. The smaller differences in loading between treatments were observed in the study sites where WT levels were near to the ground surface.

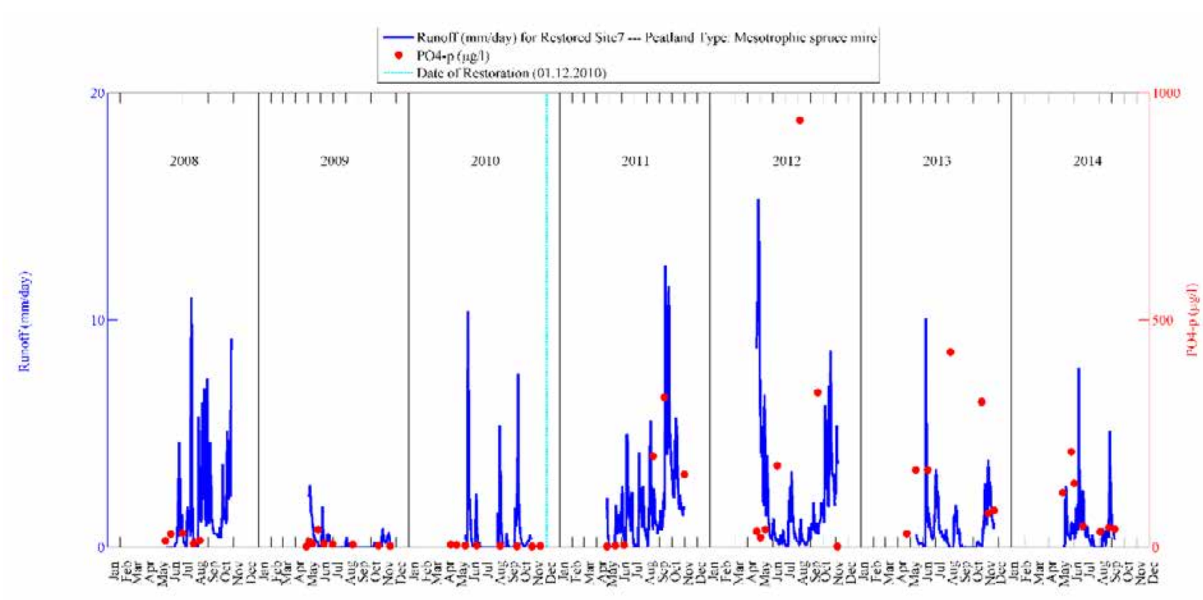

Figure 9. Example of effect of restoration at site 7 on PO_4-P concentrations. Other figures can be found in the appendixes.

The calculated loading values (g/ha/day) for the entire monitoring period for study sites with runoff data are shown in Table 3. Similarly to concentration levels, during the first year of restoration, an increase in several of the water quality parameters found. However, after few years of restoration, loading levels are getting closer to the situation before restoration but are still slightly larger than the condition in their pristine counterparts. The Kruskal-Wallis statistical tests revealed that the difference in the median of loading before and after restoration for all monitoring years were statistically significant. When median loading of all years after restoration, were compared against loading before restoration only few statistically significant increase were observed (Kruskal-Wallis test, $p<0.05$). Most of those were in the data of sites 7 and 86 where restoration increased P_{tot} and Fe loading. PO_4-P load increased only in site 7 whereas N_{tot} in site 86 and NH_4-N load in sites 7 and 103/1. Loadings in restored sites were significantly large when compared to loadings in pristine sites, typically 100 % larger (Table 4).

Table 4. Typical loading (median values) from drained/restored peatlands and their pristine counterparts where runoff was continuously monitored.

DOC (g/ha day) Site/Year	2008	2009	2010	2011	2012	2013	2014	Increase (%)*
7	0.594	0.234	0.258	1.057	1.095	0.437	0.444	99
17	0.082	0.126	0.043	0.099	0.139	0.057	0.057	
85	0.499	0.122	0.174	0.239	0.294	0.185	0.151	91
86	0.142	0.073	0.148	0.218	0.468	0.252	0.202	100
94	0.311	0.181	0.197	0.216	0.361	0.263	0.228	
105		0.137	0.441	0.275	0.830	0.292	0.373	102
116		0.135	0.384	0.410	0.386	0.225	0.282	
1031	0.375	0.109	0.186	0.254	0.350	0.296	0.243	97
1032	0.109	0.127	0.218	0.236	0.739	0.382	0.305	

Fe (g/ha day) Site/Year	2008	2009	2010	2011	2012	2013	2014	Increase (%)
7	7.534	4.685	4.610	25.35	27.626	9.223	10.13	99.541
17	1.935	2.843	0.854	2.365	3.926	1.805	1.795	
85	4.765	3.299	3.831	6.012	5.731	3.762	3.537	100.697
86	1.500	1.009	1.954	3.608	5.849	3.832	3.250	100.074
94	14.28	8.662	3.269	6.704	25.827	14.105	6.918	
105		1.100	6.185	3.528	12.437	4.400	6.248	100.968
116		1.171	5.958	9.023	8.551	3.760	5.788	
1031	4.272	2.981	4.275	6.777	6.819	6.449	5.732	4.841
1032	3.595	3.445	4.742	6.566	16.739	9.648	9.276	

Tot-N (g/ha day) Site/Year	2008	2009	2010	2011	2012	2013	2014	Increase (%)
7	11.293	4.318	4.079	22.566	25.779	13.425	9.397	99
17	1.665	2.055	0.623	1.591	2.412	1.000	0.900	
85	6.215	1.968	2.619	4.315	6.123	3.131	2.720	98
86	3.076	1.233	2.229	4.861	11.329	5.874	3.962	98
94	3.570	1.101	0.802	1.504	3.933	2.592	1.965	
105		0.727	6.599	3.782	14.843	5.012	5.608	103
116		0.731	5.701	6.300	6.105	3.705	3.922	
1031	5.862	2.187	3.413	4.634	7.049	6.625	5.105	96
1032	2.391	2.501	3.764	4.272	14.739	8.450	5.595	

NH_4-N (g/ha day) Site/Year	2008	2009	2010	2011	2012	2013	2014	Increase (%)
7	0.259	0.084	0.064	0.415	1.345	3.264	0.692	99.846
17	0.108	0.040	0.013	0.037	0.059	0.031	0.021	
85	0.066	0.054	0.050	0.075	1.342	0.116	0.041	100.079
86	0.085	0.026	0.046	0.103	0.676	0.287	0.050	100.091
94	0.175	0.140	0.166	0.156	0.233	0.186	0.168	
105		0.135	0.215	0.178	0.487	0.256	0.192	102.241
116		0.166	0.250	0.250	0.255	0.254	0.165	
1031	0.180	0.190	0.114	0.182	0.486	0.690	0.244	98.482
1032	0.216	0.103	0.127	0.072	0.485	0.319	0.066	

NO_{2+3}-N (g/ha day) Site/Year	2008	2009	2010	2011	2012	2013	2014	Increase (%)
7		0.077	0.015	0.180	0.180	0.067		99.529
17		0.026	0.004	0.021	0.013	0.006		
85		0.025	0.015	0.036	0.068	0.025		100.070
86		0.019	0.006	0.046	0.114	0.037		100.018
94		0.140	0.156	0.163	0.195	0.162		
105		0.161	0.244	0.162	0.248	0.150		100.665
116		0.172	0.713	0.493	0.405	0.233		
1031		0.107	0.105	0.098	0.081	0.314		96.342
1032		0.092	0.112	0.065	0.213	0.170		

Solid (g/ha day) Site/Year	2008	2009	2010	2011	2012	2013	2014	Increase (%)
7		3.307	3.746	13.068	32.243	12.030	18.87	103.634
17		6.488	0.995	2.319	3.072	1.158	1.351	
85		157	175	159.68	167.37	159.86	162.6	91.758
86		1.253	5.569	7.257	26.089	9.293	8.237	100.006
94		1425	152	126.97	171.74	148.09	134.9	
105		1288	117	103.51	143.74	102.73	143.7	75.162
116		1060	116	112.44	114.79	104.31	135.2	
1031		114	114	107.26	110.18	108.98	110.5	98.960
1032		1.620	2.900	4.939	23.677	11.542	12.75	

Tot-P (g/ha day) Site/Year	2008	2009	2010	2011	2012	2013	2014	Increase (%)
7	0.409	0.191	0.079	2.480	3.548	1.604	0.982	99.802
17	0.130	0.172	0.023	0.033	0.217	0.141	0.099	
85	0.205	0.071	0.049	0.115	0.316	0.087	0.063	101.020
86	0.109	0.041	0.039	0.889	1.635	0.423	0.177	100.041
94	0.262	0.140	0.162	0.148	0.182	0.191	0.149	
105		0.121	0.419	0.179	0.681	0.750	0.362	79.946
116		0.123	0.395	0.208	0.237	0.199	0.232	
1031	0.187	0.053	0.060	0.061	0.196	0.249	0.135	98.538
1032	0.062	0.063	0.070	0.055	0.223	0.127	0.168	

PO_4-P (g/ha day) Site/Year	2008	2009	2010	2011	2012	2013	2014	Increase (%)
7	0.188	0.064	0.017	2.045	2.479	1.233	0.630	100.003
17	5.662	0.080	0.008	0.015	0.143	0.085	0.070	
85	0.116	0.020	0.013	0.043	0.111	0.030	0.019	100.042
86	2.550	0.010	0.007	0.706	0.969	0.231	0.083	104.300
94	3.352	0.129	0.140	0.130	0.145	0.150	0.137	
105		0.657	0.225	0.112	0.250	0.162	0.173	101.316
116		1.941	0.213	0.131	0.137	0.118	0.164	
1031	1.340	0.015	0.018	0.016	0.082	0.118	0.061	101.278
1032	5.710	0.020	0.023	0.011	0.054	0.037	0.020	

Drained | Restored | Pristine

*Increase in loading after restoration operation in comparison against pristine counterparts

Discussion

Restoration has in most cases been successful in raising the WT level to or slightly above the WT level of similar pristine sites and in restoring the natural fluctuation of the WT level. The effect of restoration on WT level, however, varies between sites and especially between mire types. In general, the changes in WT elevation were much bigger in wooded mire types, i.e. spruce mires and pine mires than in open fens. However, this difference is more likely caused due to the drainage conditions before restoration than the peatland type. In some of the study sites, hardly any difference was observed between WT levels of drained and pristine sites before or after restoration which indicated poor drainage conditions. The WT elevation variation of pristine counterparts is a result of natural variable in hydrology during the monitoring years. This can be seen in Fig. 3 where the groundwater data of the drained/restored and its pristine counterpart has been divided into two stages as before and after restoration. The mean WT of pristine sites (with open circle in the figure 3) vary before (light blue) and after (dark blue) restoration periods of their drained counterparts indicating changes due to climate e.g. precipitation. If this assumed climatic driven variation is removed from the data of drained/restored sites, the remaining difference can be stated to be caused by restoration. From this viewpoint, the natural variation of WT was less than 20% of observed chances in WT of restored sites in 12 peatlands and 20-50% in six peatlands. In two peatlands (Suo-87 and Suo-102) the natural variation in WT explained changes in WT of the restored sites.

According to the intensive pore water quality monitoring from 27 drained/restored peatlands, restoration has significantly decreased the concentration of nitrogen and DOC in comparison to the years when the sites were drained. Also pore water phosphorus concentrations were somewhat lower after restoration than before actions but this was not statistically significant. Although water quality in pore water was improved due to restoration, concentrations were still little higher than natural level in the areas.

Disturbance of peat materials and subsequent increase of WT during and after restoration had caused leaching of nutrients and ions in the restored sites. The largest increase of nutrients in both stream water and pore water samples were observed during the first years of restoration and showed a decreasing value thereafter. This leaching can be due to the exposure of fresh organic matter after restoration. Loading after restoration for phosphorus and nitrogen were similar than previously reported specific load from peatland forestry as ditch maintaining or forestry operation has been done in the area (Joensuu 2002, Haapalehto et al. 2014). Some larger loads were observed for example from site 7, however, specific loads are not totally comparable since sites in this study set do not include monitoring data from winter periods. Nevertheless, a large variation between study sites observed and before making final conclusions, the effect of different hydrological years need to be analyzed alongside this study. Previous studies have observed large fluctuation of loading after restoration operation even in individual sites and therefore it is highly recommended to continue monitoring the restored sites to get a better and full understanding of long term variations and equilibrium conditions at restored sites. Different hydrological years may affect leaching of nutrients and would be important to monitor response of restored sites against climatic factors.

Generally, it can be concluded based on the results of this study that restoration has reached its main target for elevated WT, which launch re-developing of peat layers. This is essential to towards reaching the global biodiversity target of halting the loss of biodiversity (CBD). However, restoration operation causes disturbance of the peat layers and elevated load to water course sand in some cases, e.g. when restoring large parts of the catchment of a headwater stream, special water protection actions should be taken to minimize negative effects in the recipient water courses. Since part of study sites contained rather high WT already before restoration, their WT might return to pristine conditions even without restoration operation. However, in many cases, drainage has also affected the chemical composition of the pore water and especially the flow patterns of water in the mire so that drainage has affected the habitat types and species in the mires detrimentally. This and the effect of changing hydrological conditions still need further analysis.

References

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Joensuu S. 2002. Effects of ditch network maintenance and sedimentation ponds on export loads of suspended solids and nutrients from peatland forests. Metsäntutkimuslaitos, Vantaan tutkimuskeskus. Metsäntutkimuslaitoksen tiedonantoja, 868.

Appendix 1: Characteristics of the study sites

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Mesotrophic sites

Community	Monitoring point	Peatland type	Treatment	Counterpart	Area (ha)	Catchment area (ha)	Vegetation type	Starting year of studies	Starting year of hydrology monitoring	Restoration time
Heinävesi	**Suo-4**	Spruce mire	Drained/ restored	suo15			MK	2010	2010	24.10.-4.11.2011
Heinävesi	**Suo-5**	Spruce mire	Drained/ restored	suo15			MK	2010	2010	24.9.-2.10.2012
Ruovesi	**Suo-7/Pato-7**	Spruce mire	Drained/ restored	suo17, pato17		6.9	Mkmu/tkg	2008	2008	1.-15.12.2010
Nurmes	**Suo-8**	Spruce mire	Drained/ restored	-			MK	2007	2008	1.9.-23.10.2008
Savonlinna	**Suo-15**	Spruce mire	Pristine	suo 4, suo5			MK	2010	2010	
Juupajoki	**Suo-17/Pato-17**	Spruce mire	Pristine	suo7, pato7		6.5	MK	2008	2008	
Kinnula	**Suo-102**	Fen	Drained/ restored	suo113			Snmu	2007	2009	6.-10.12.2010
Ruovesi	**Suo-103/Pato-103/1 and 103/2**	Fen	Drained/ restored	103/2 and 103/1		51.5	Snmu	2008	2008	28.-29.11.2011
Taivalkoski	**Suo-105/Pato-105**	Fen	Drained/ restored	suo116, pato116,		65	SN mu	2009	2009	Sept.-Oct. 2011
Siikalatva	**Suo-107**	Fen	Drained/ restored	suo117			SN	2008	2008	Oct.r- Nov. 2009
Pudasjärvi	**Suo-108**	Fen	Drained/ restored	suo118			riSN mu	2010	2010	2012
Perho	**Suo-113**	Fen	Pristine	suo102			MeSN/osin LN	2009	2009	
Taivalkoski	**Suo-116/Pato-116**	Fen	Pristine	suo105, pato105		65	SN	2009	2009	
Haapavesi	**Suo-117**	Fen	Pristine	suo107			SN	2008	2008	
Pudasjärvi	**Suo 118**	Fen	Pristine	suo108			ri SN	2010		

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Eutrophic sites

Community	Monitoring point	Peatland type	Treatment	Counterpart	Area (ha)	Catchment area (ha)	Vegetation type	Starting year of studies	Starting year of hydrology monitoring	Restoration time
Hyvinkää	**Suo-23**	Spruce mire	Drained/ restored	suo32			RhK	2010	2010	18.-22.10.2010
Yläne	**Suo-24**	Spruce mire	Drained/ restored	suo35			Rhtkg	2008	2010	9.-13.1.2012
Hämeenlinna	**Suo-25**	Spruce mire	Drained/ restored	suo35			RhTKg	2008	2008	22.10.2009
Taivalkoski	**Suo-28**	Spruce mire	Drained/ restored	suo39			RhKmu	2010	2010	Nov. 2011
Karkkila	**Suo-32**	Spruce mire	Pristine	suo23			SaK	2007	2010	
Kalvola	**Suo-35**	Spruce mire	Pristine	suo24, suo25			RhK	2008	2008	
Taivalkoski	**Suo-39**	Spruce mire	Pristine	suo28			RhK	2010	2010	
Taivalkoski	**Suo-121**	Fen	Drained/ restored	suo128			LKMu	2010	2010	Sept. 2011
Suomussalmi	**Suo-123**	Fen	Drained/ restored	suo130			LRmu	2010	2010	2012
Tervola	**Suo-124**	Fen	Drained/ restored	suo132			KeLRmu-oj, luhtainen	2009	2013	Aug. 2013
Taivalkoski	**Suo-128**	Fen	Pristine	suo121			LK (lähteinen)	2010	2010	
Suomussalmi	**Suo-130**	Fen	Pristine	suo123			LR	2010	2010	
Tervola	**Suo-132**	Fen	Pristine	suo124			ReLR	2009	2013	

Ombrotrophic sites

Community	Monitoring point	Peatland type	Treatment	Counterpart	Area (ha)	Catchment area (ha)	Vegetation type	Starting year of studies	Starting year of hydrology monitoring	Restoration time
Laitila	**Suo-42**	Pine mire	Drained/ restored	suo52			IRmu	2009	2010	29.8.-9.9.2011
Karstula	**Suo-46**	Pine mire	Drained/ restored	suo56			IRMu	2009	2009	11.-15.10.2010
Saarijärvi	**Suo-48**	Pine mire	Drained/ restored	suo56			IRMu	2009	2009	13.-17.9.2010
Nurmes	**Suo-49**	Pine mire	Drained/ restored	-			IR	2006	2008	16.7.-20.8.2009
Laitila	**Suo-52**	Pine mire	Pristine	suo42			IR	2009	2010	
Karstula	**Suo-56**	Pine mire	Pristine	suo46, suo48			TR	2009	2009	

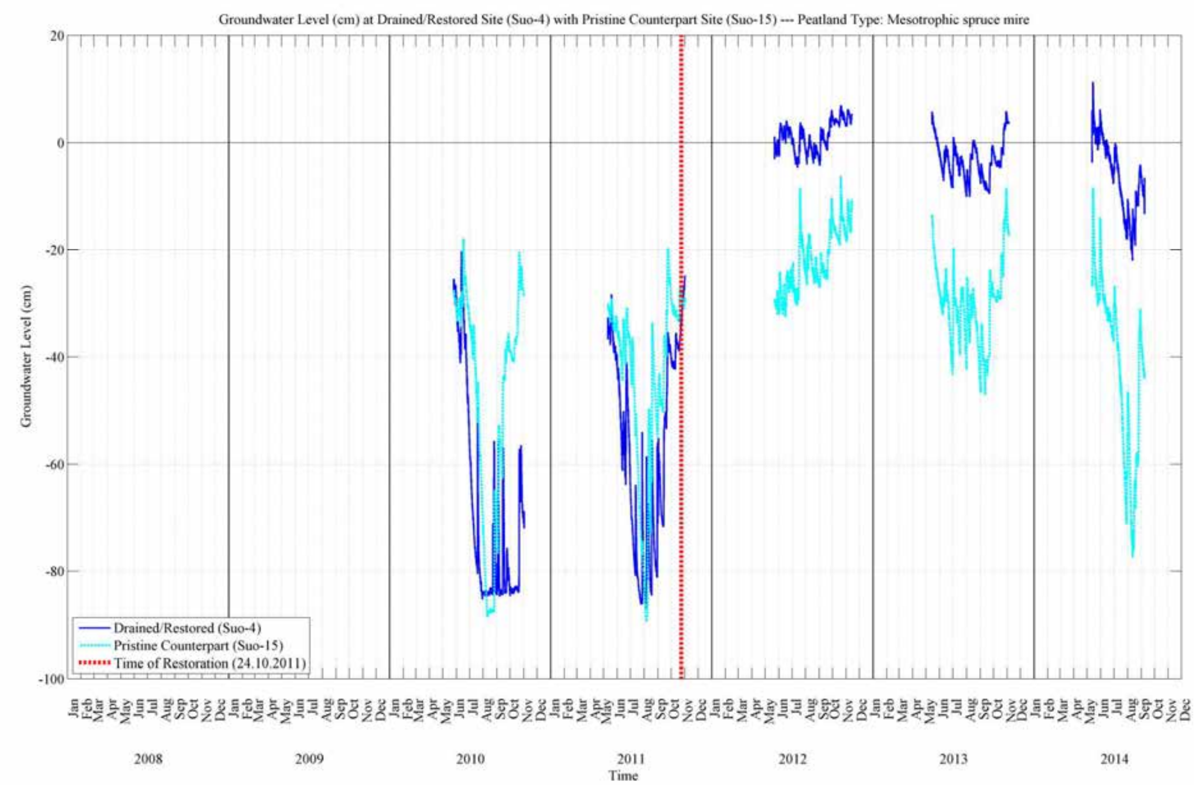
Minerotrophic sites

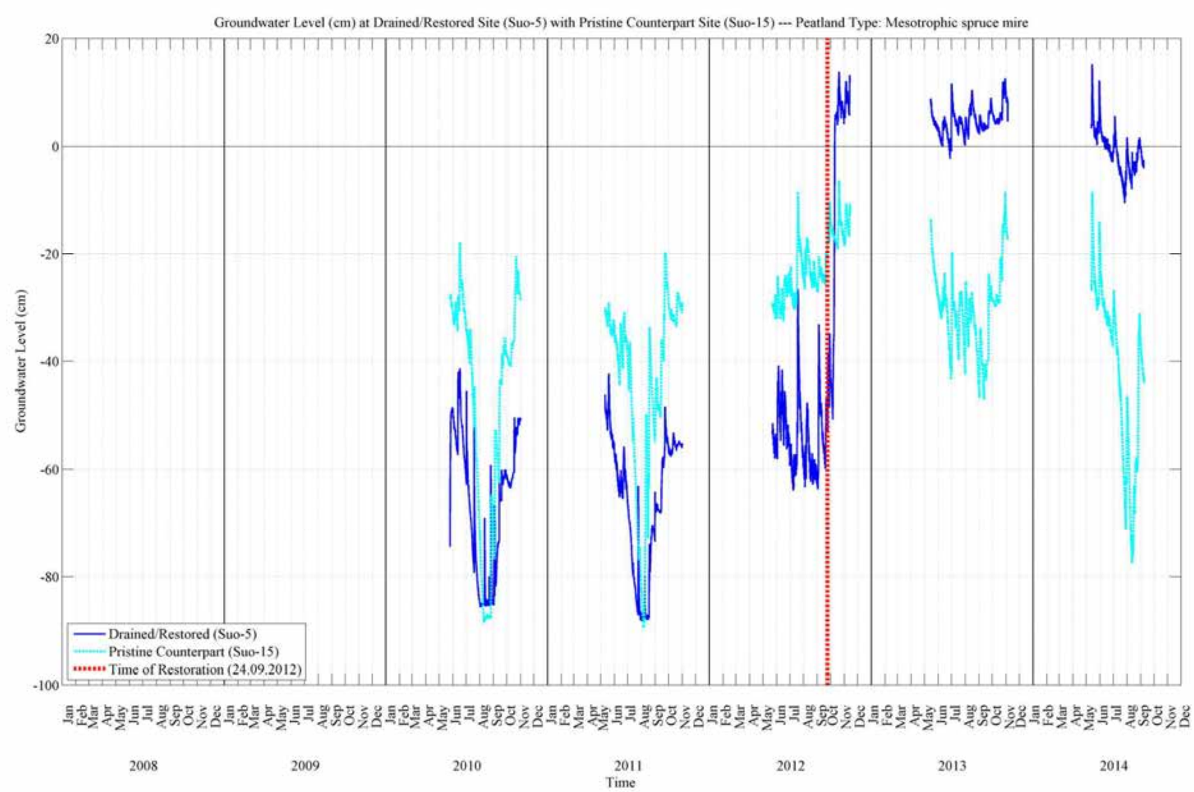
Community	Monitoring point	Peatland type	Treatment	Counterpart	Area (ha)	Catchment area (ha)	Vegetation type	Starting year of studies	Starting year of hydrology monitoring	Restoration time
Ilomantsi	**Suo-63**	Pine mire	Drained/ restored	suo73			SRmu	2007	2009	26.7.-31.8.2011.
Pudasjärvi	**Suo-65**	Pine mire	Drained/ restored	suo75			SRmu	2007	2008	Nov. 2009
Pyhäntä	**Suo-68**	Pine mire	Drained/ restored	suo78			SRmu	2009	2009	1.8.2011
Haapavesi	**Suo-69**	Pine mire	Drained/ restored	suo78			Srmu	2009	2009	Nov. 2011 - Sept. 2012
Ilomantsi	**Suo-73**	Pine mire	Pristine	suo63			SR	2007	2009	
Pudasjärvi	**Suo-75**	Pine mire	Pristine	suo65			SR	2007	2008	
Pyhäntä	**Suo-78**	Pine mire	Pristine	suo68, suo 69			SR	2009	2009	

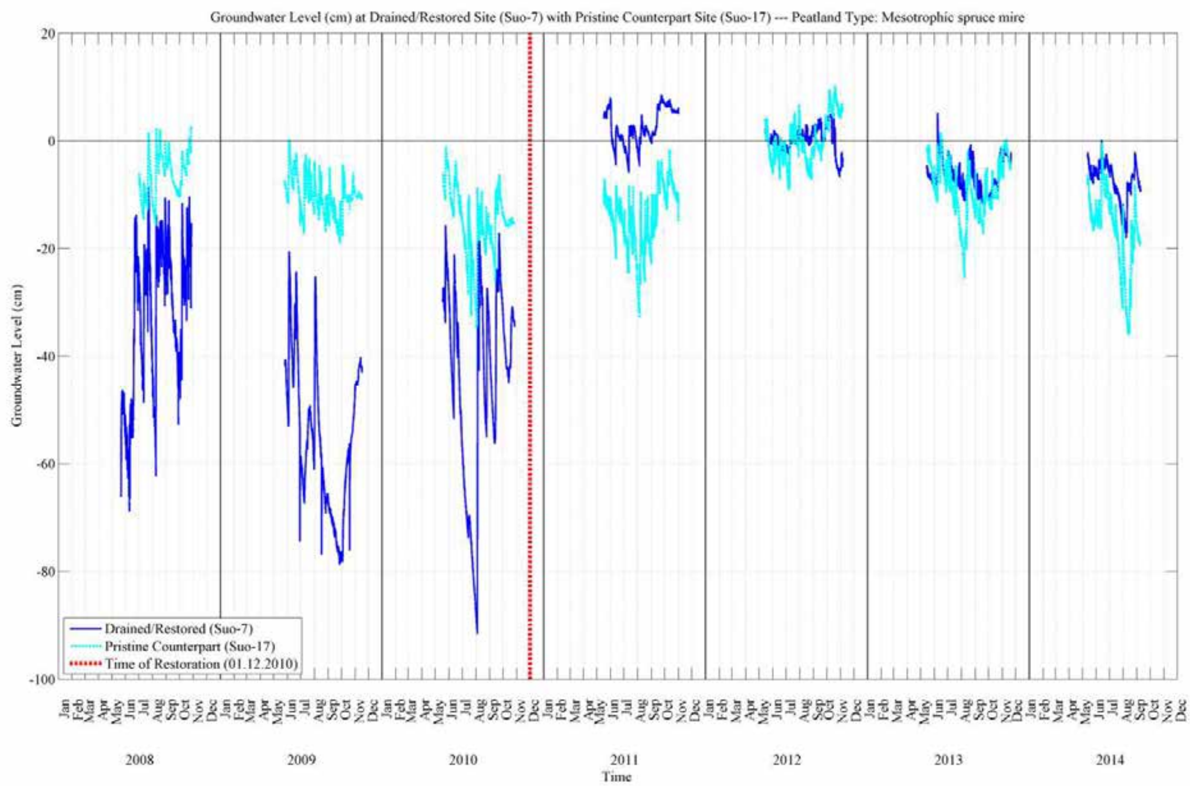
Oligotrophic sites

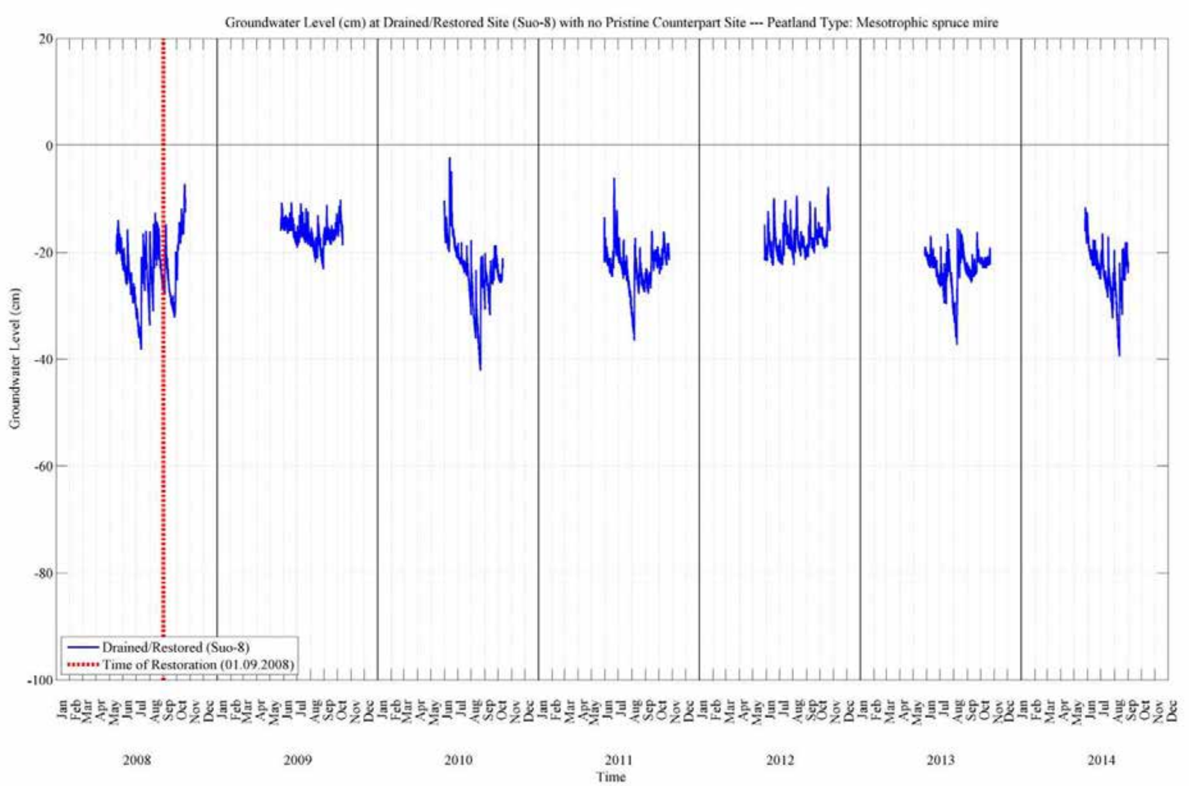
Community	Monitoring point	Peatland type	Treatment	Counterpart	Area (ha)	Catchment area (ha)	Vegetation type	Starting year of studies	Starting year of hydrology monitoring	Restoration time
Ruovesi	**Suo-85/Pato-85**	Fen	Drained/ restored	suo94, pato94		30	LkNMu	2008	2008	26.11.-10.12.2010
Ruovesi	**Suo-86/Pato-86**	Fen	Drained/ restored	suo94, pato95		22	LkNMu	2008	2008	5.-17.11.2010
Nurmes	**Suo-87**	Fen	Drained/ restored	suo96			LkNR	2007	2008	24.- 29.9.2008
Ruovesi	**Suo-94/Pato-94**	Fen	Pristine	suo85, suo86, pato85, pato86		12	LkN	2008	2008	
Nurmes	**Suo-96**	Fen	Pristine	suo87			LkNR	2007	2008	

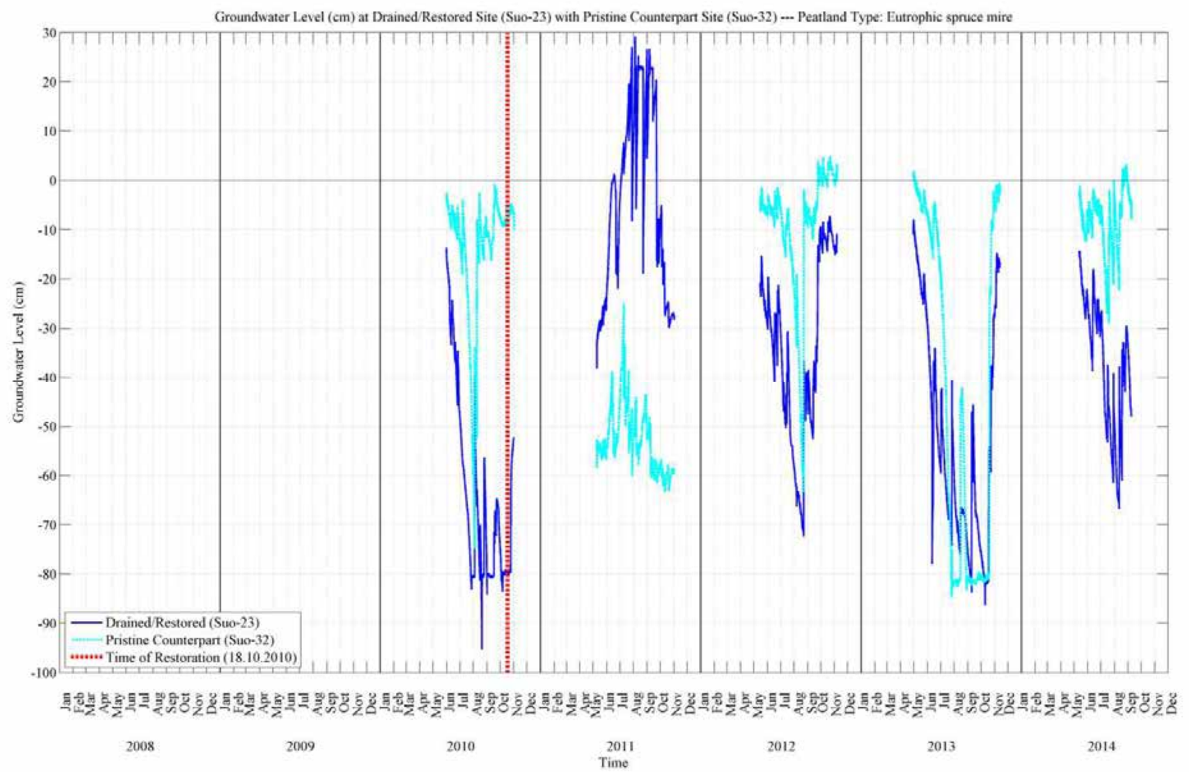
Appendix 2: Water table elevation (WT) in the sites with continuous WT monitoring during 2008-2014. The arrow shows the starting date of restoration.

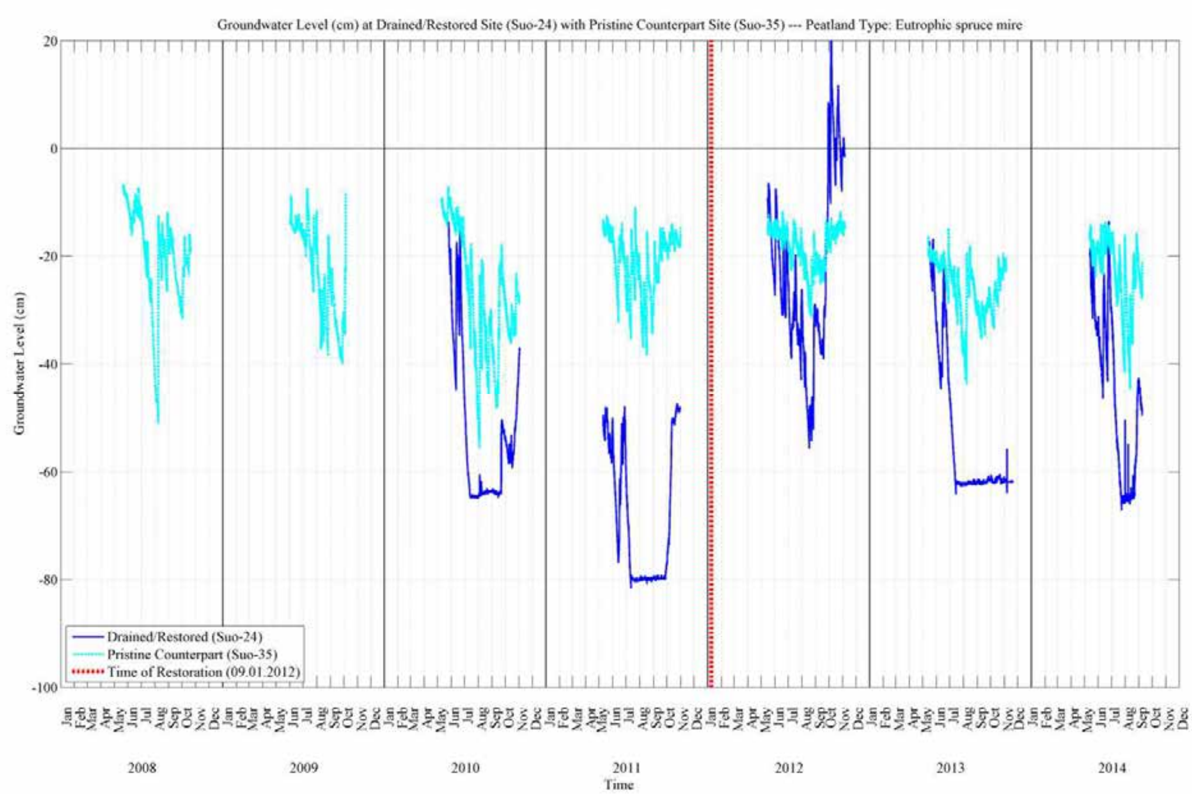


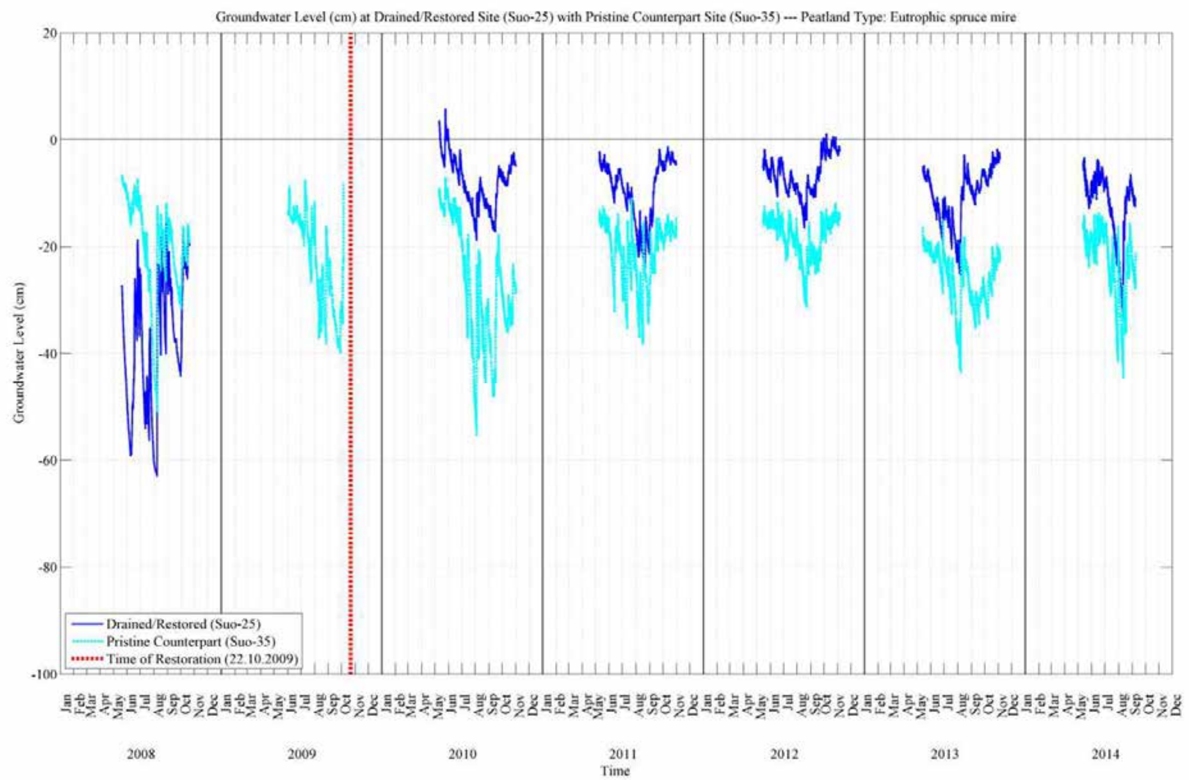


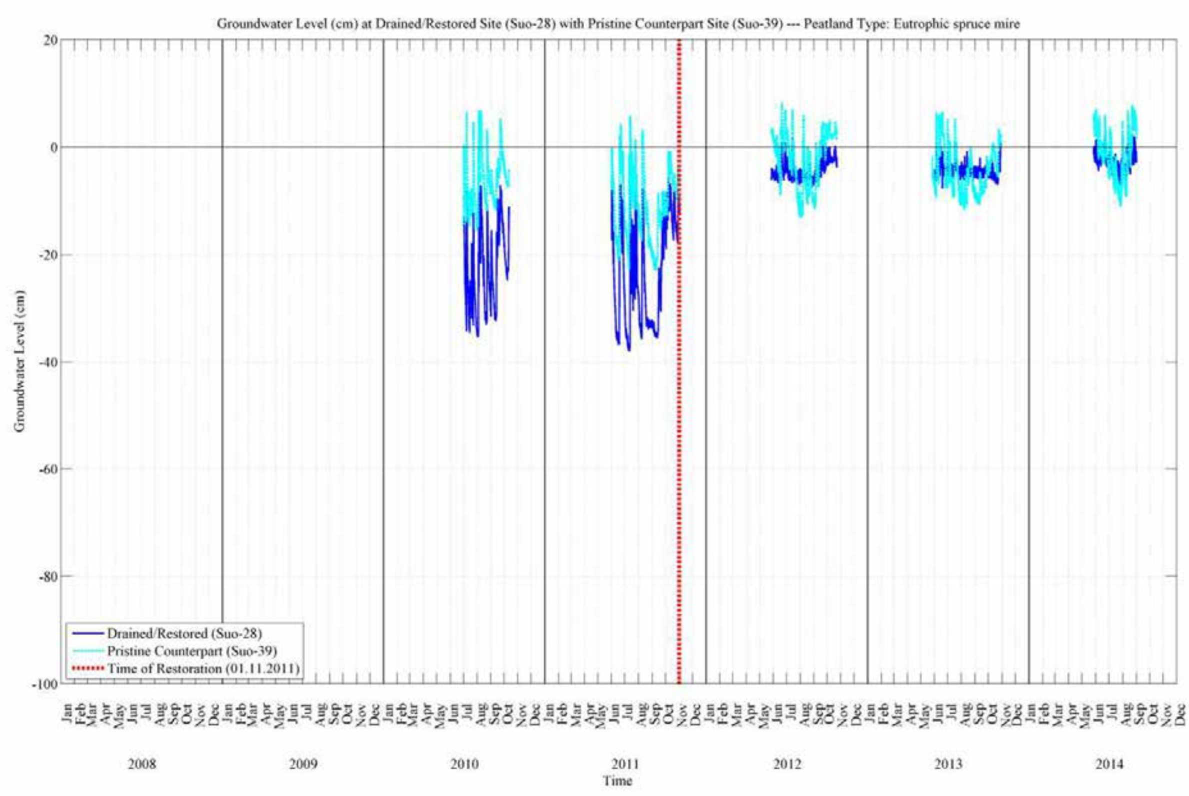

Groundwater Level (cm) at Drained/Restored Site (Suo-7) with Pristine Counterpart Site (Suo-17) --- Peatland Type: Mesotrophic spruce mire
Groundwater Level (cm)
Drained/Restored (Suo-7)
Pristine Counterpart (Suo-17)
Time of Restoration (01.12.2010)
20
0
-20
-40
-60
-80
-100
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
2008
2009
2010
2011
2012
2013
2014
Time

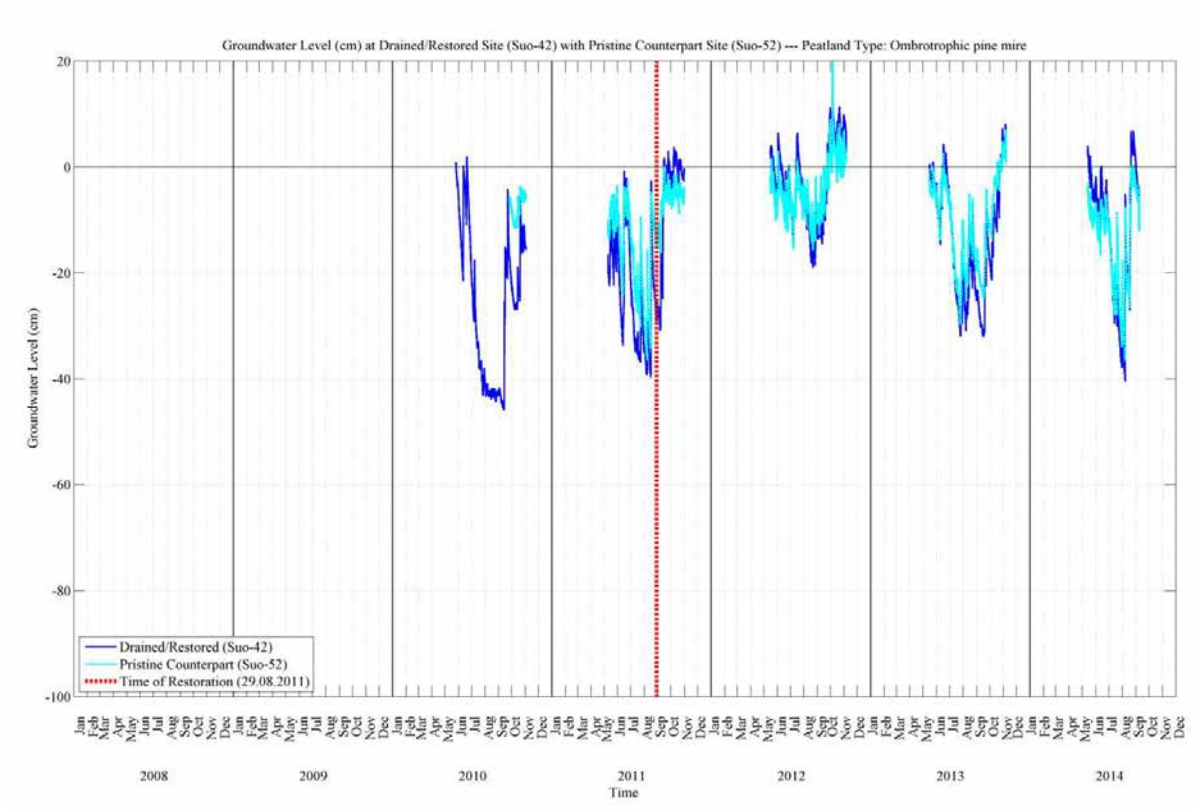

Groundwater Level (cm) at Drained/Restored Site (Suo-8) with no Pristine Counterpart Site --- Peatland Type: Mesotrophic spruce mire
Groundwater Level (cm)
Drained/Restored (Suo-8)
Time of Restoration (01.09.2008)
20
0
-20
-40
-60
-80
-100
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
2008
2009
2010
2011
2012
2013
2014
Time

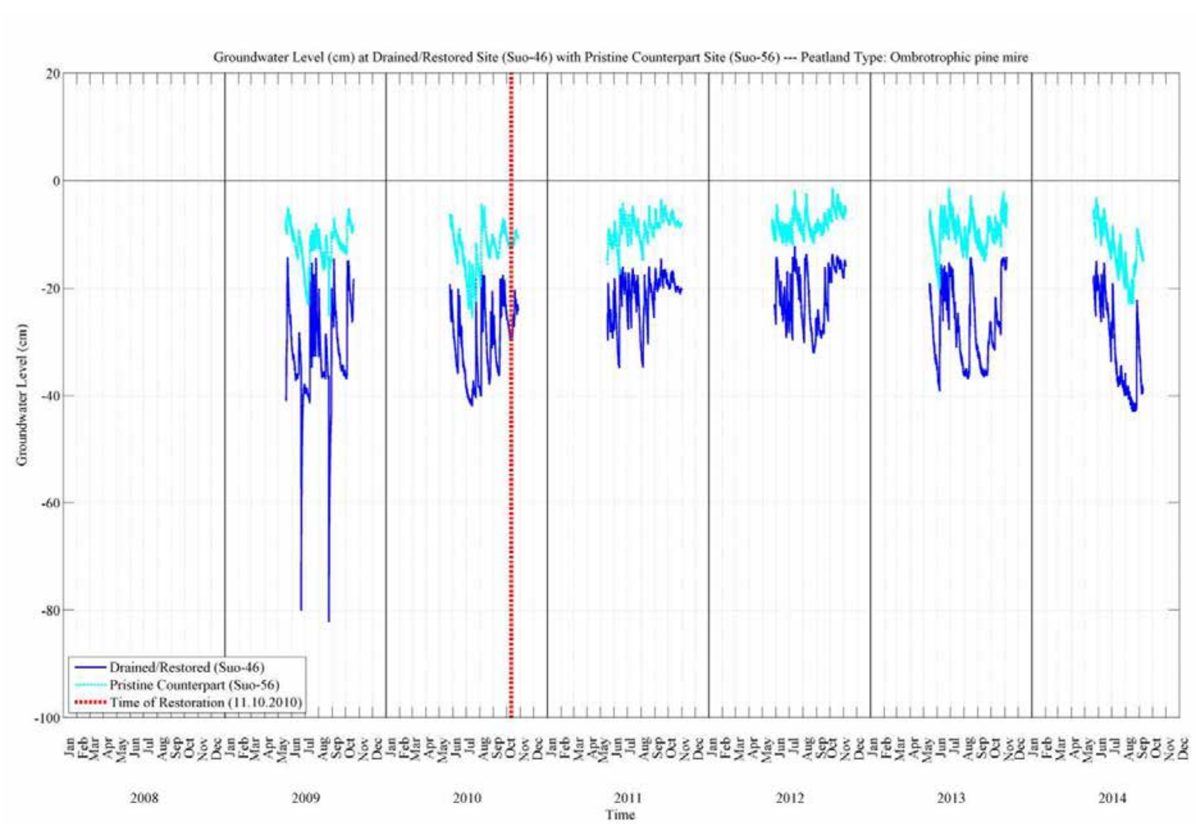

Groundwater Level (cm) at Drained/Restored Site (Suo-23) with Pristine Counterpart Site (Suo-32) --- Peatland Type: Eutrophic spruce mire
Groundwater Level (cm)
Drained/Restored (Suo-23)
Pristine Counterpart (Suo-32)
Time of Restoration (18.10.2010)
2008
2009
2010
2011
2012
2013
2014
Time

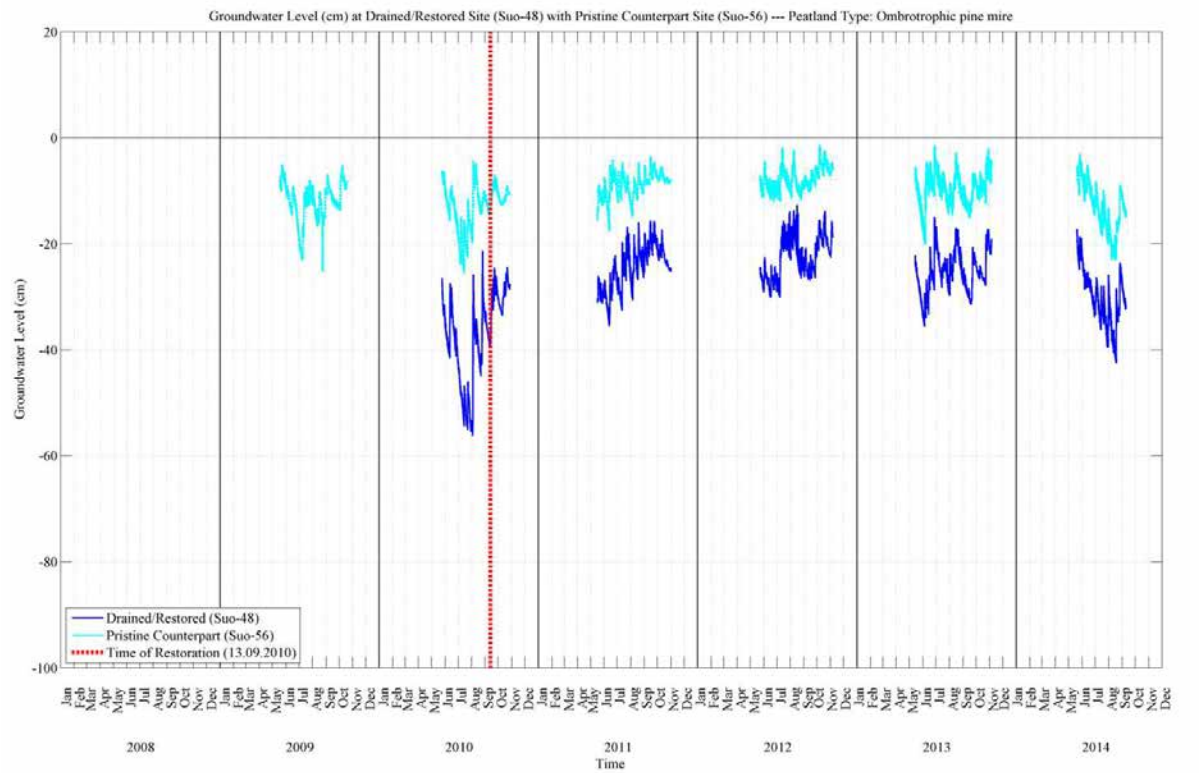

Groundwater Level (cm) at Drained/Restored Site (Suo-24) with Pristine Counterpart Site (Suo-35) --- Peatland Type: Eutrophic spruce mire
Groundwater Level (cm)
Drained/Restored (Suo-24)
Pristine Counterpart (Suo-35)
Time of Restoration (09.01.2012)
2008
2009
2010
2011
2012
2013
2014
Time

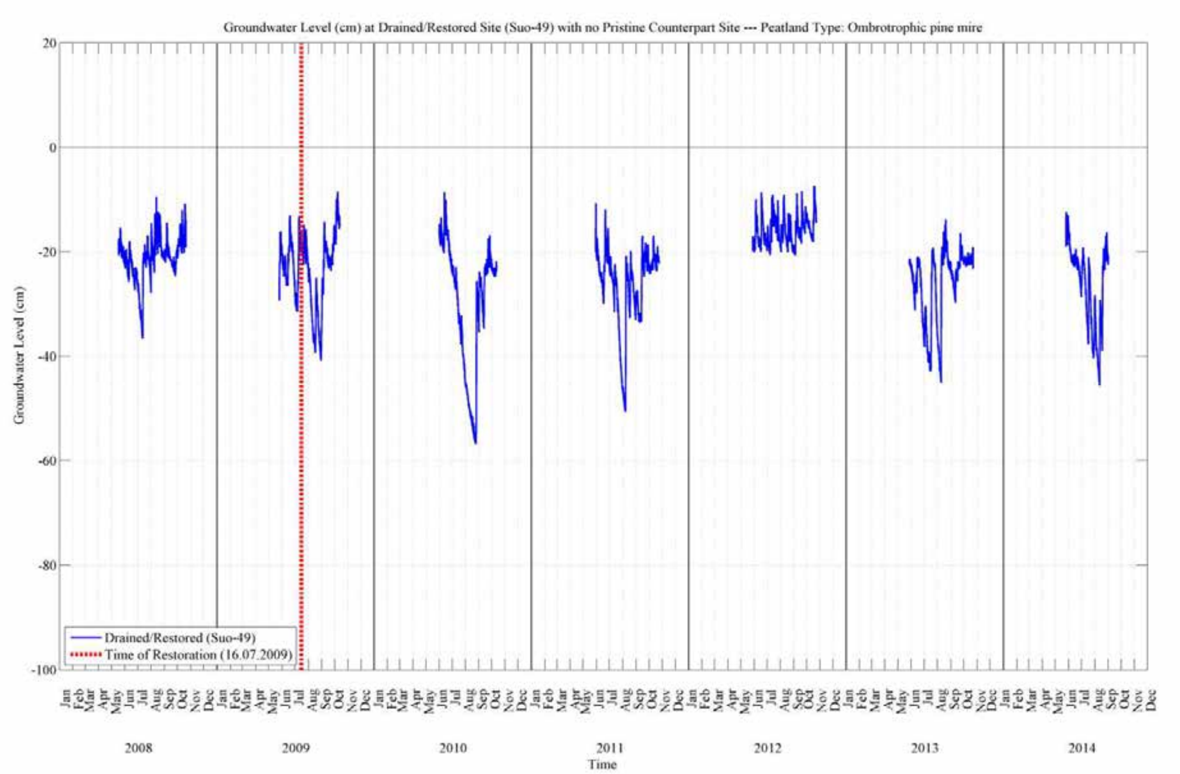

Groundwater Level (cm) at Drained/Restored Site (Suo-25) with Pristine Counterpart Site (Suo-35) --- Peatland Type: Eutrophic spruce mire
Groundwater Level (cm)
Drained/Restored (Suo-25)
Pristine Counterpart (Suo-35)
Time of Restoration (22.10.2009)
Time
2008
2009
2010
2011
2012
2013
2014

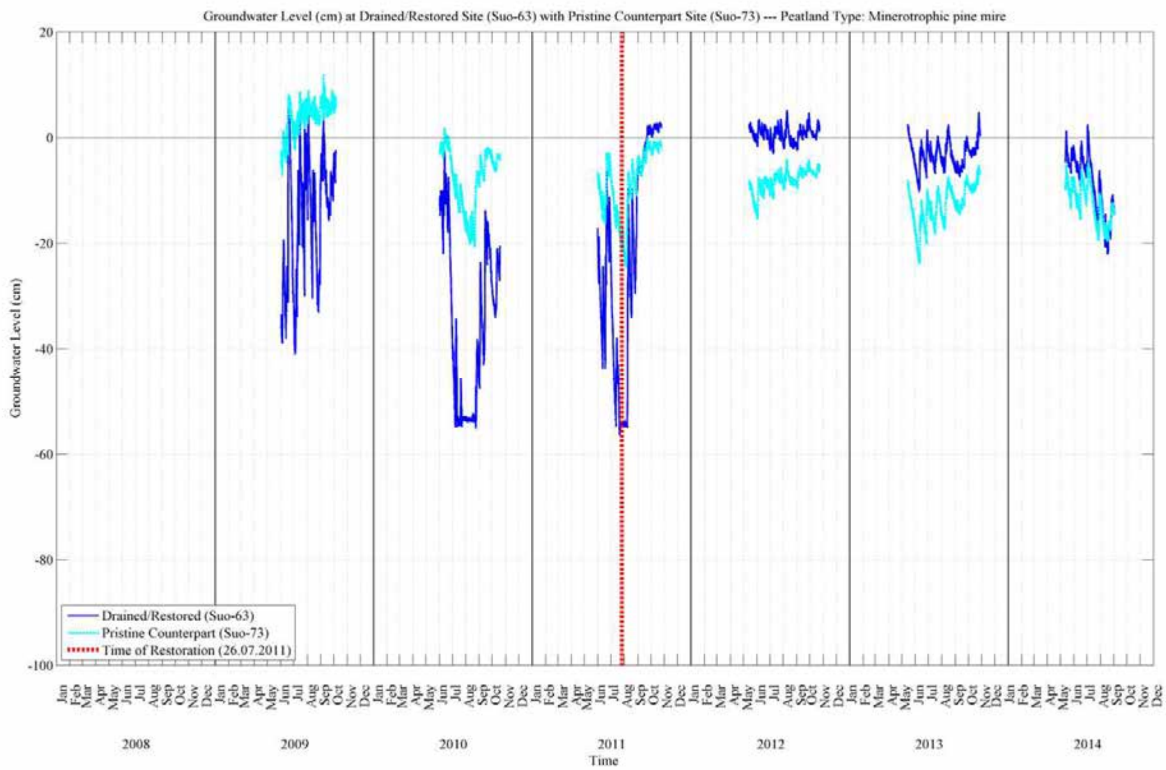

Groundwater Level (cm) at Drained/Restored Site (Suo-28) with Pristine Counterpart Site (Suo-39) --- Peatland Type: Eutrophic spruce mire
Groundwater Level (cm)
Drained/Restored (Suo-28)
Pristine Counterpart (Suo-39)
Time of Restoration (01.11.2011)
Time
2008
2009
2010
2011
2012
2013
2014

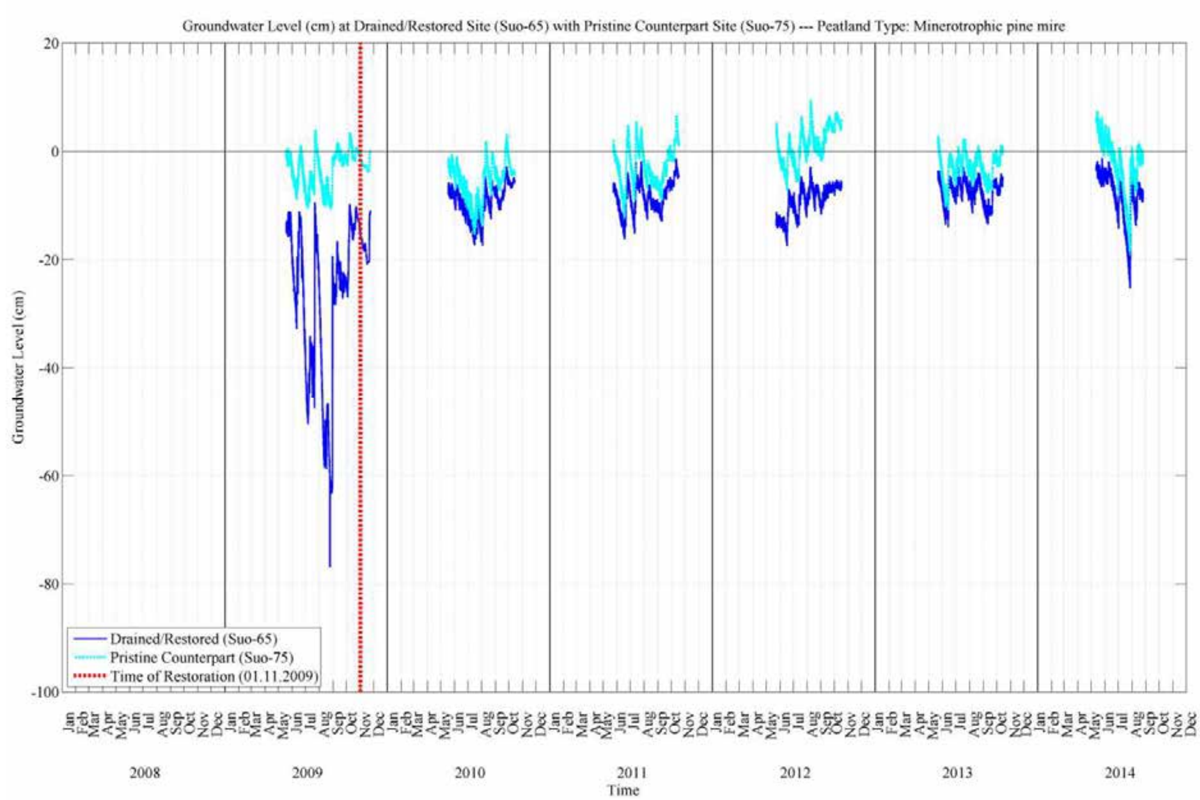

Groundwater Level (cm) at Drained/Restored Site (Suo-42) with Pristine Counterpart Site (Suo-52) --- Peatland Type: Ombrotrophic pine mire
Groundwater Level (cm)
Drained/Restored (Suo-42)
Pristine Counterpart (Suo-52)
Time of Restoration (29.08.2011)
2008
2009
2010
2011
2012
2013
2014
Time

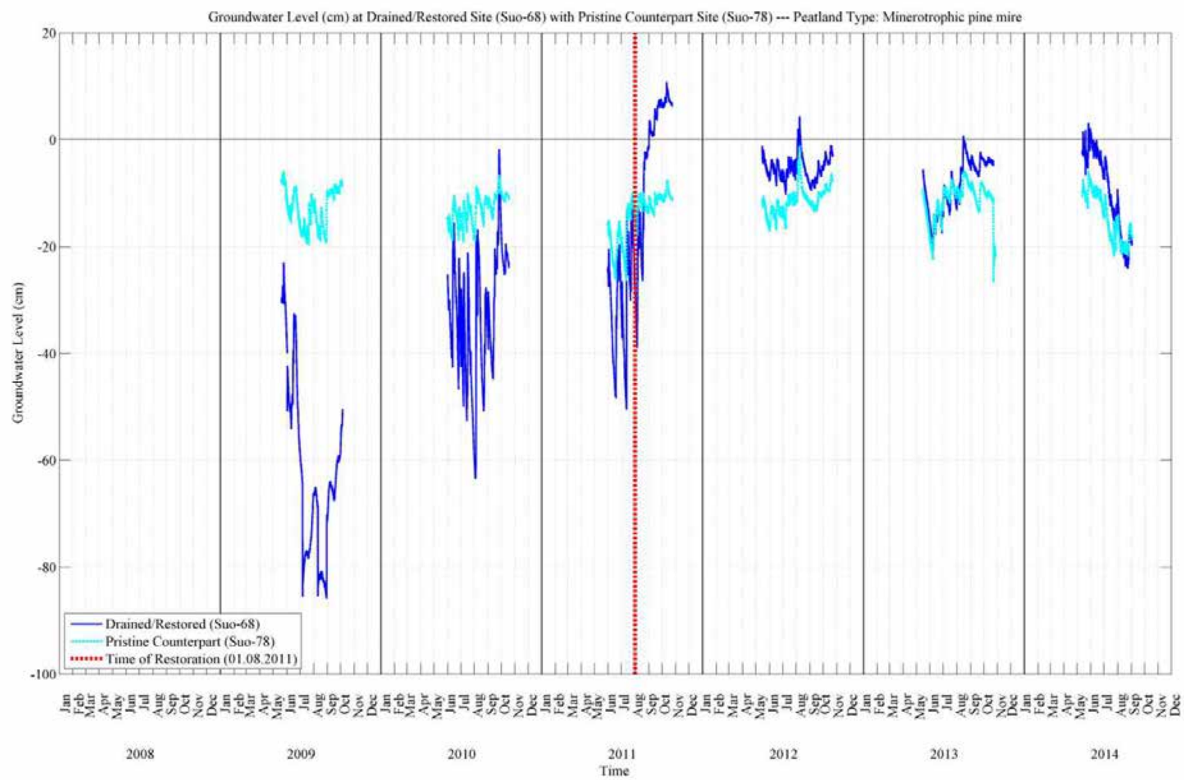

Groundwater Level (cm) at Drained/Restored Site (Suo-46) with Pristine Counterpart Site (Suo-56) --- Peatland Type: Ombrotrophic pine mire
Groundwater Level (cm)
Drained/Restored (Suo-46)
Pristine Counterpart (Suo-56)
Time of Restoration (11.10.2010)
2008
2009
2010
2011
2012
2013
2014
Time

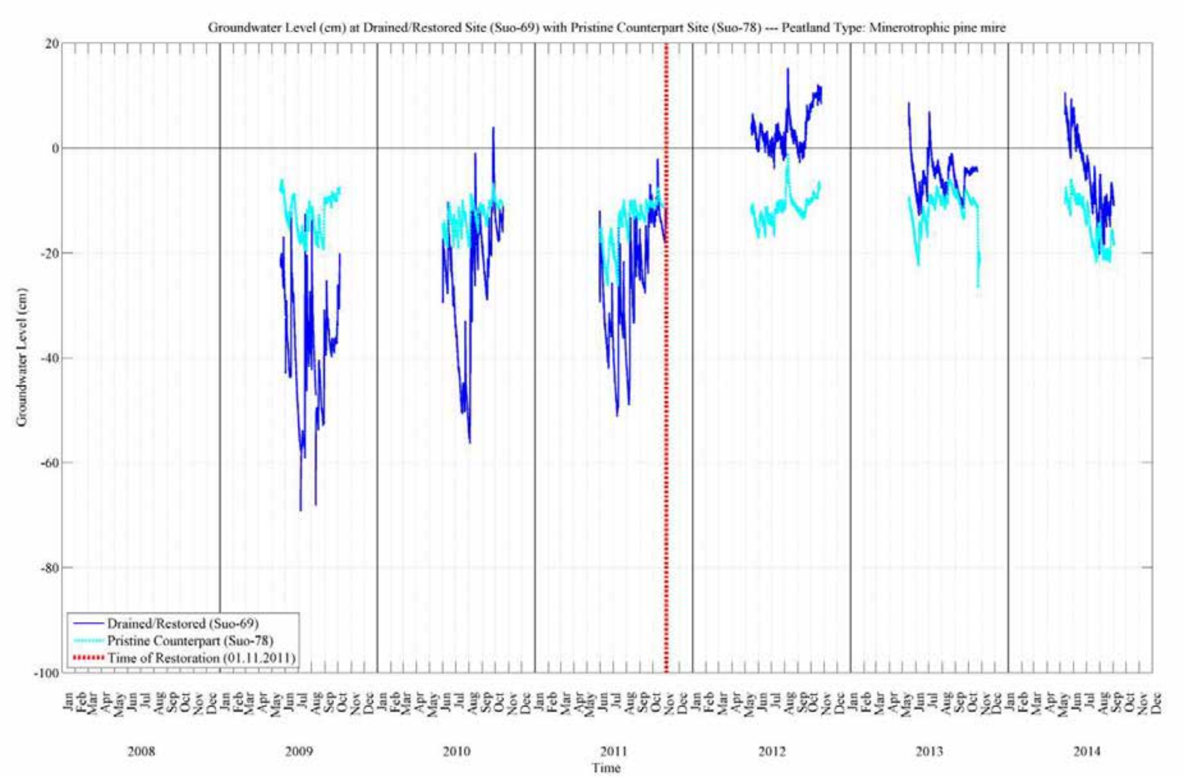

Groundwater Level (cm) at Drained/Restored Site (Suo-48) with Pristine Counterpart Site (Suo-56) --- Peatland Type: Ombrotrophic pine mire
Groundwater Level (cm)
Drained/Restored (Suo-48)
Pristine Counterpart (Suo-56)
Time of Restoration (13.09.2010)
Time
2008
2009
2010
2011
2012
2013
2014

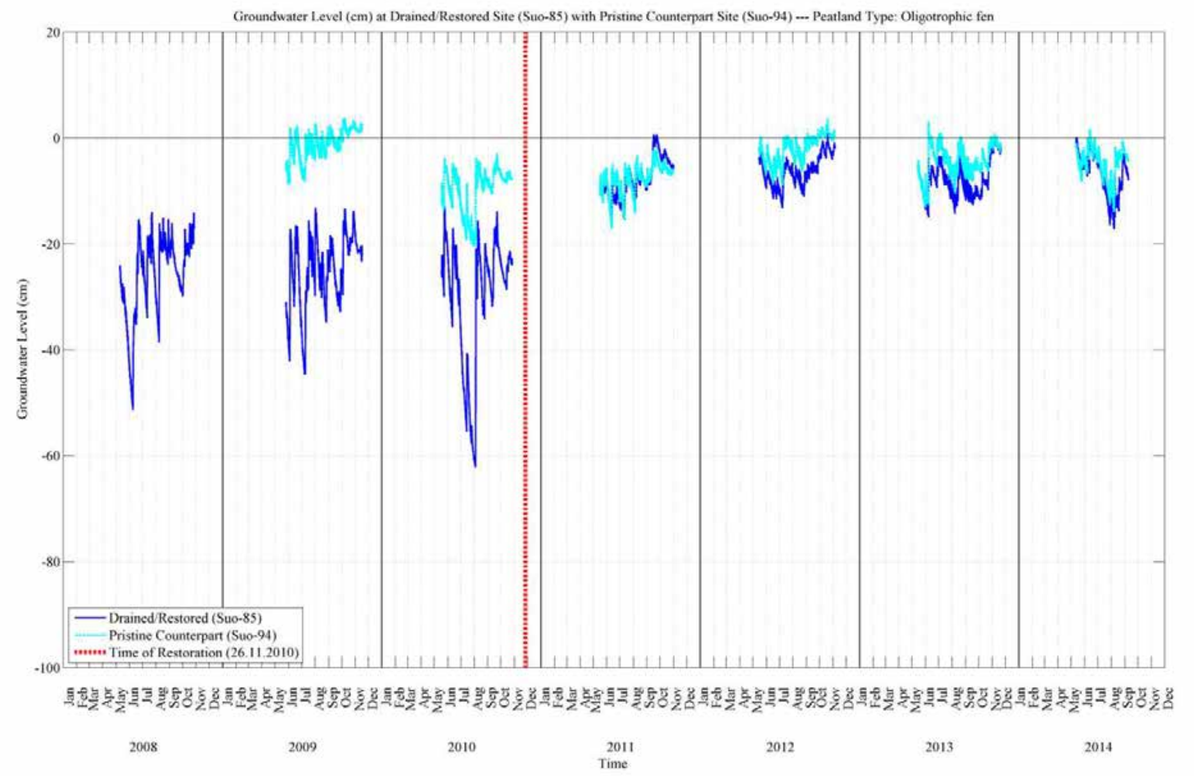

Groundwater Level (cm) at Drained/Restored Site (Suo-49) with no Pristine Counterpart Site --- Peatland Type: Ombrotrophic pine mire
Groundwater Level (cm)
Drained/Restored (Suo-49)
Time of Restoration (16.07.2009)
Time
2008
2009
2010
2011
2012
2013
2014

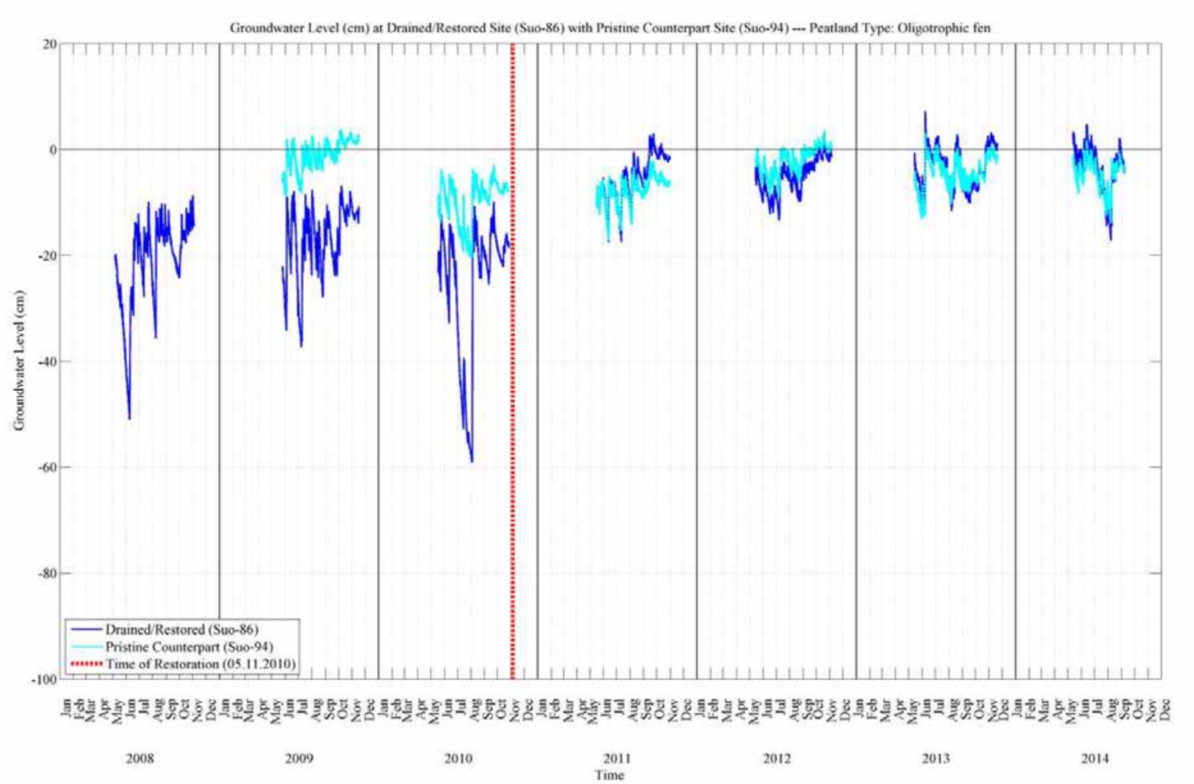

Groundwater Level (cm) at Drained/Restored Site (Suo-63) with Pristine Counterpart Site (Suo-73) --- Peatland Type: Minerotrophic pine mire
Groundwater Level (cm)
Drained/Restored (Suo-63)
Pristine Counterpart (Suo-73)
Time of Restoration (26.07.2011)
2008
2009
2010
2011
2012
2013
2014
Time

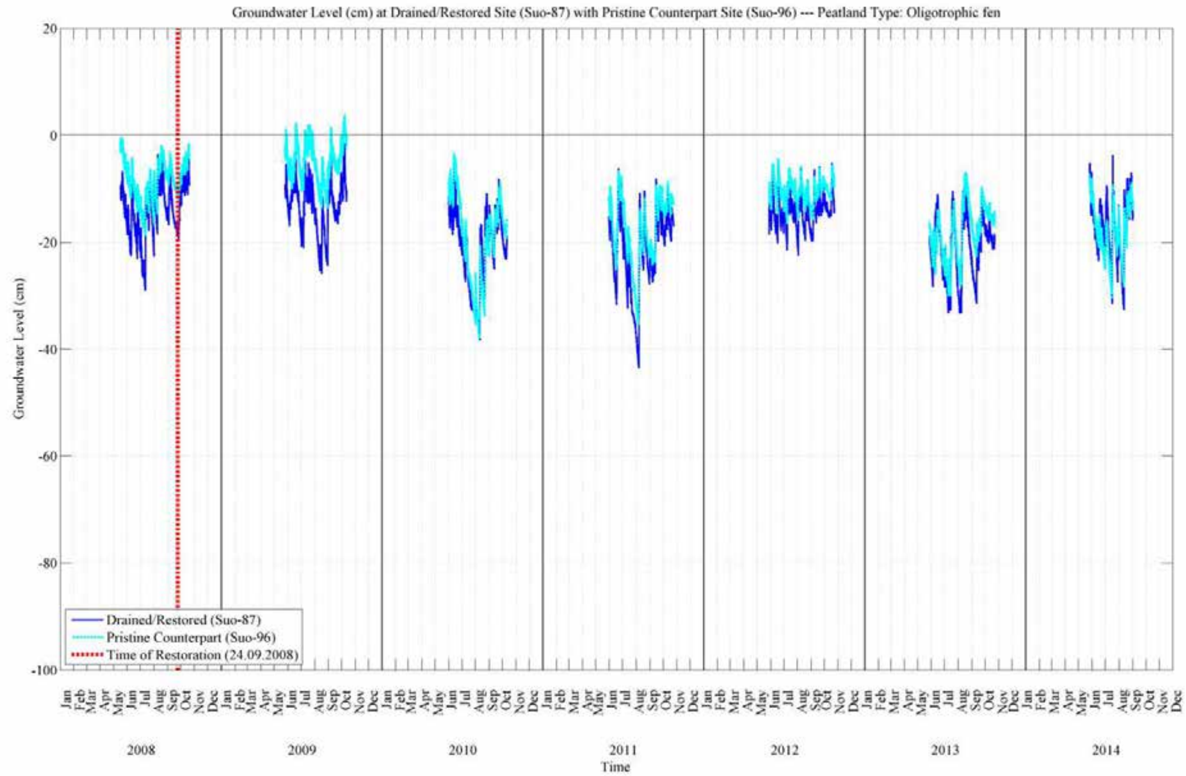

Groundwater Level (cm) at Drained/Restored Site (Suo-65) with Pristine Counterpart Site (Suo-75) --- Peatland Type: Minerotrophic pine mire
Groundwater Level (cm)
Drained/Restored (Suo-65)
Pristine Counterpart (Suo-75)
Time of Restoration (01.11.2009)
2008
2009
2010
2011
2012
2013
2014
Time

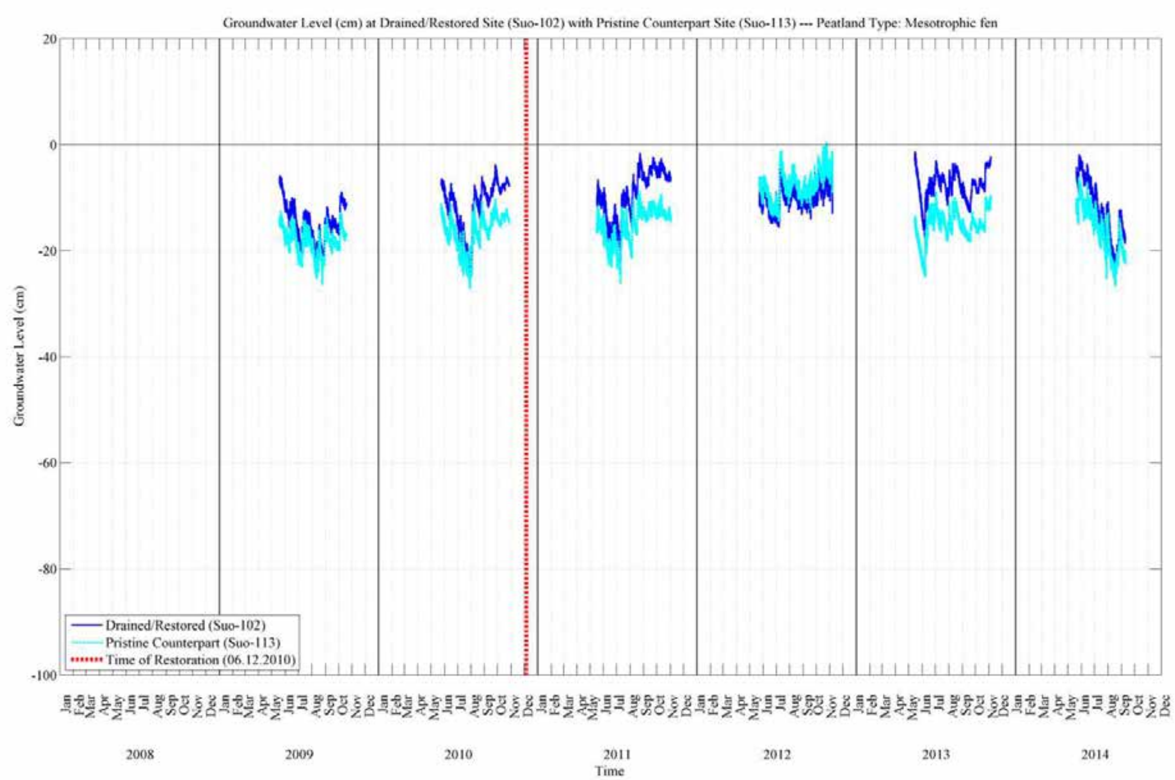

Groundwater Level (cm) at Drained/Restored Site (Suo-68) with Pristine Counterpart Site (Suo-78) --- Peatland Type: Minerotrophic pine mire
Groundwater Level (cm)
Time
Drained/Restored (Suo-68)
Pristine Counterpart (Suo-78)
Time of Restoration (01.08.2011)
2008
2009
2010
2011
2012
2013
2014

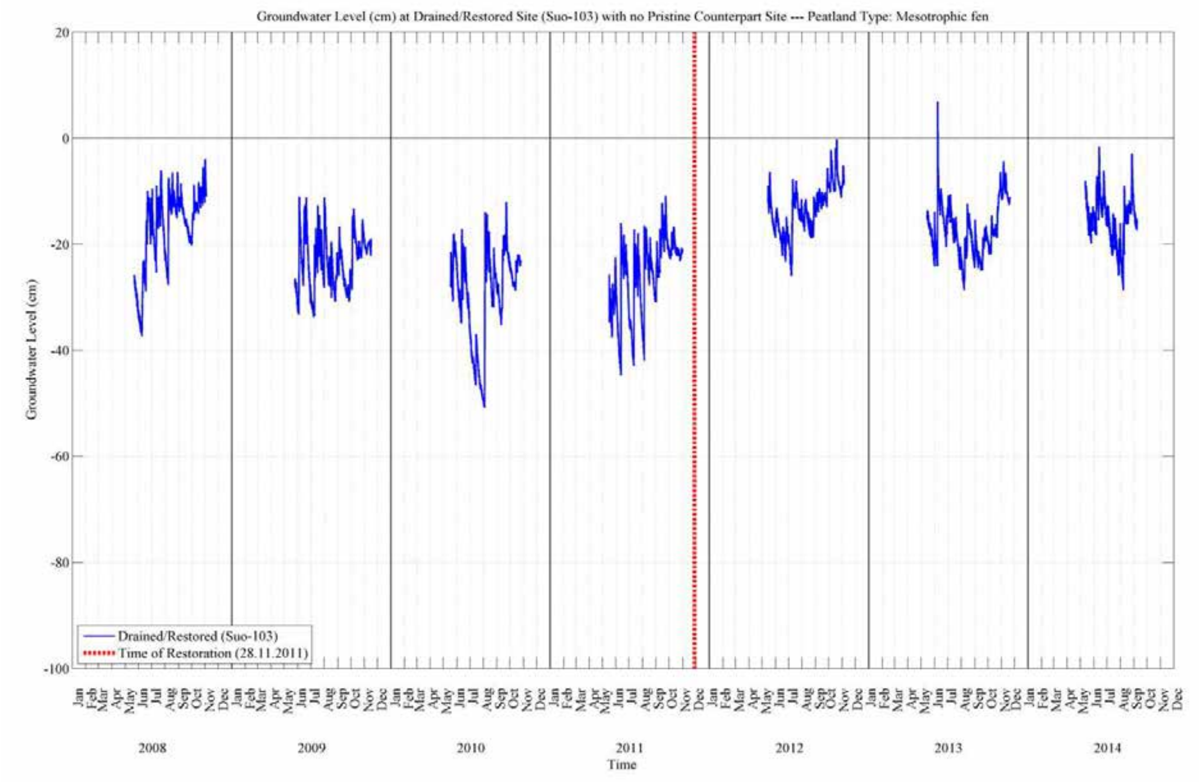

Groundwater Level (cm) at Drained/Restored Site (Suo-69) with Pristine Counterpart Site (Suo-78) --- Peatland Type: Minerotrophic pine mire
Groundwater Level (cm)
Time
Drained/Restored (Suo-69)
Pristine Counterpart (Suo-78)
Time of Restoration (01.11.2011)
2008
2009
2010
2011
2012
2013
2014

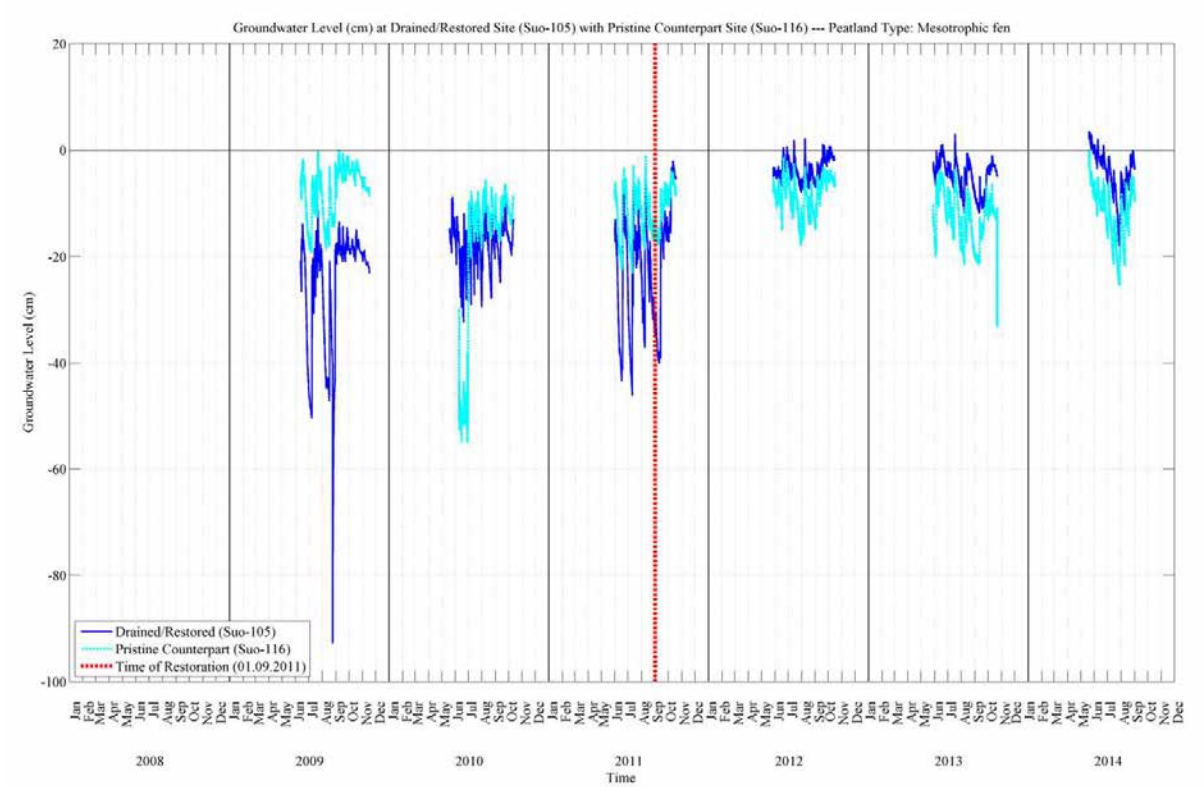

Groundwater Level (cm) at Drained/Restored Site (Suo-85) with Pristine Counterpart Site (Suo-94) --- Peatland Type: Oligotrophic fen
Groundwater Level (cm)
20
0
-20
-40
-60
-80
-100
Drained/Restored (Suo-85)
Pristine Counterpart (Suo-94)
Time of Restoration (26.11.2010)
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
2008
2009
2010
2011
2012
2013
2014
Time

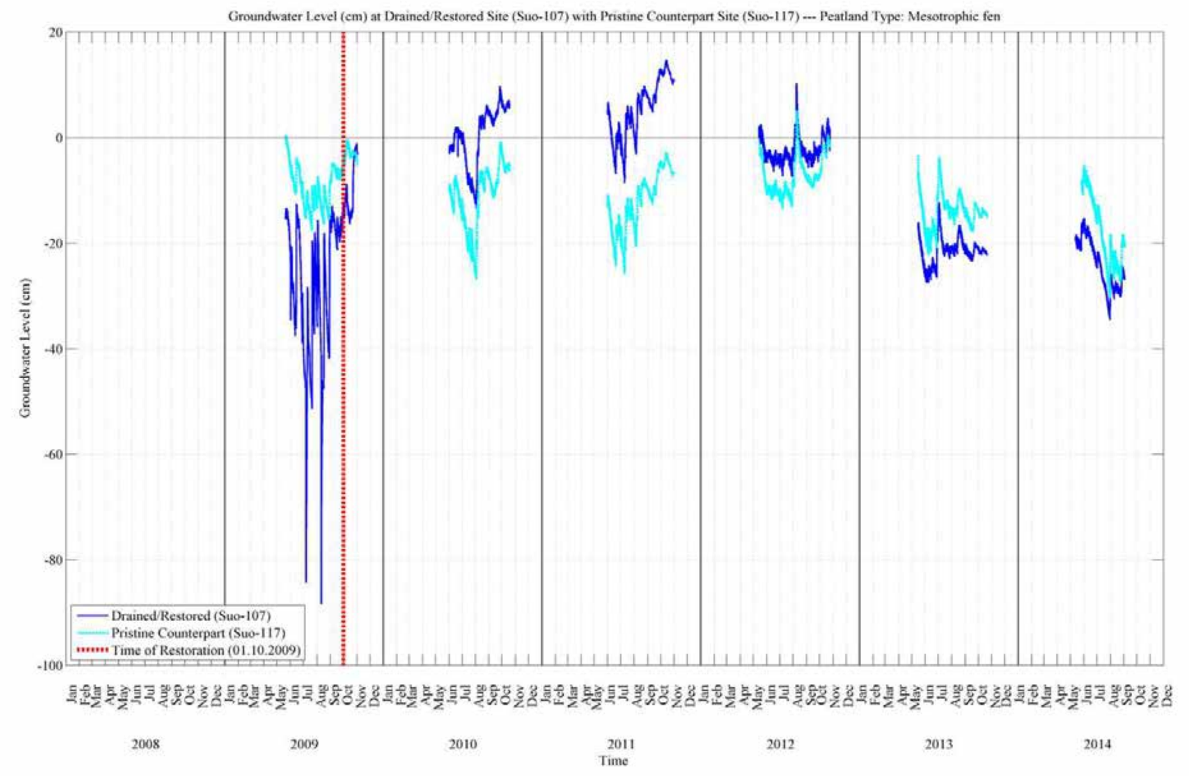

Groundwater Level (cm) at Drained/Restored Site (Suo-86) with Pristine Counterpart Site (Suo-94) --- Peatland Type: Oligotrophic fen
Groundwater Level (cm)
20
0
-20
-40
-60
-80
-100
Drained/Restored (Suo-86)
Pristine Counterpart (Suo-94)
Time of Restoration (05.11.2010)
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
2008
2009
2010
2011
2012
2013
2014
Time

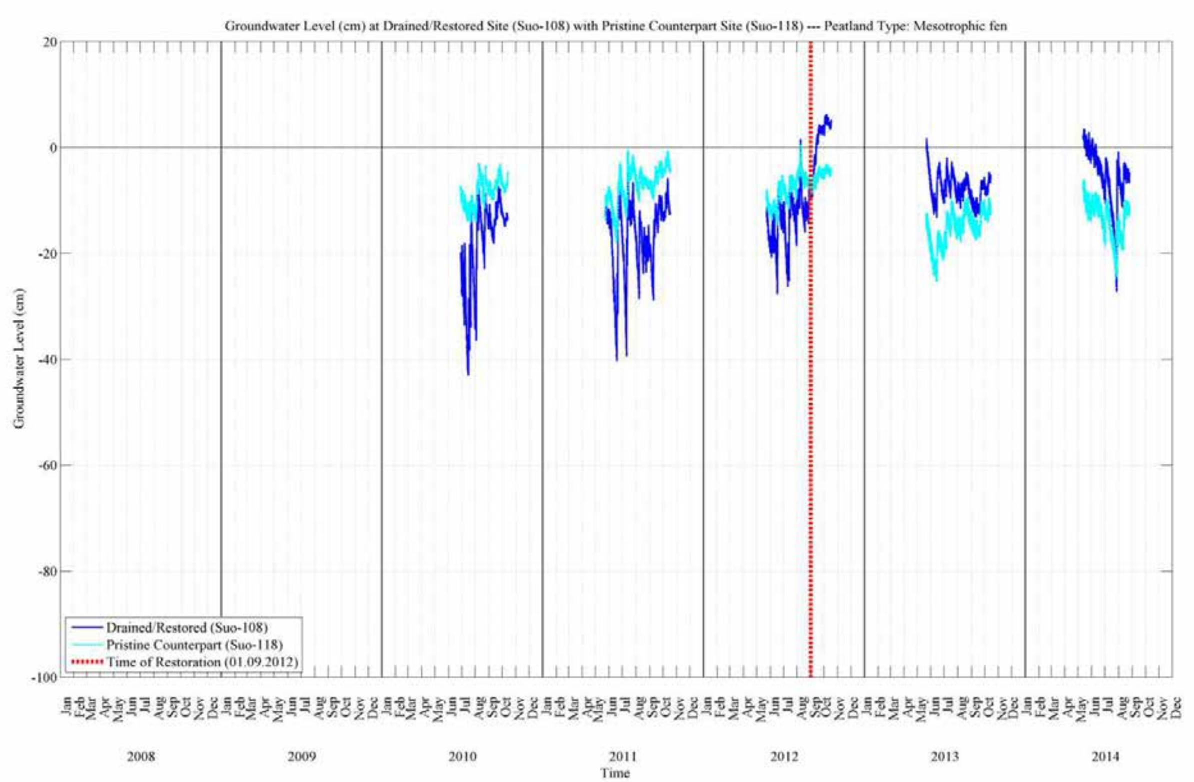

Groundwater Level (cm) at Drained/Restored Site (Suo-87) with Pristine Counterpart Site (Suo-96) --- Peatland Type: Oligotrophic fen
Groundwater Level (cm)
Drained/Restored (Suo-87)
Pristine Counterpart (Suo-96)
Time of Restoration (24.09.2008)
2008
2009
2010
2011
2012
2013
2014
Time

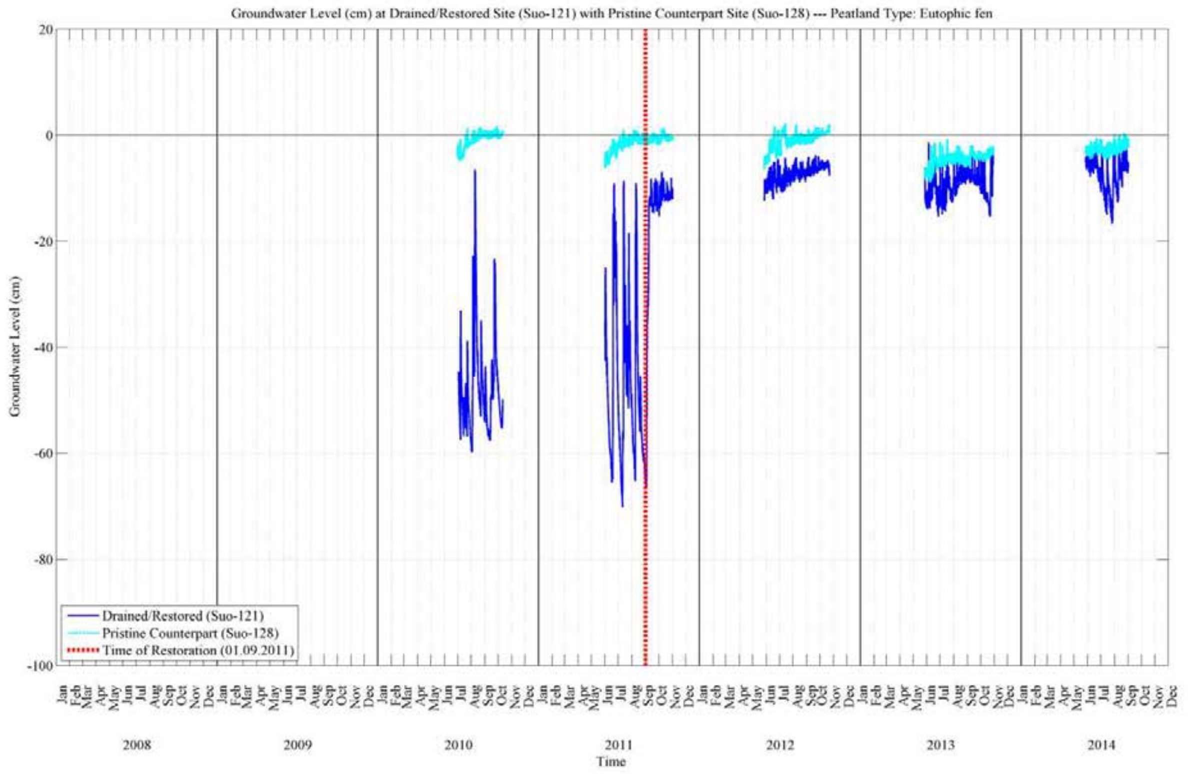

Groundwater Level (cm) at Drained/Restored Site (Suo-102) with Pristine Counterpart Site (Suo-113) --- Peatland Type: Mesotrophic fen
Groundwater Level (cm)
Drained/Restored (Suo-102)
Pristine Counterpart (Suo-113)
Time of Restoration (06.12.2010)
2008
2009
2010
2011
2012
2013
2014
Time


Groundwater Level (cm) at Drained/Restored Site (Suo-103) with no Pristine Counterpart Site --- Peatland Type: Mesotrophic fen
Groundwater Level (cm)
Drained/Restored (Suo-103)
Time of Restoration (28.11.2011)
2008
2009
2010
2011
2012
2013
2014
Time

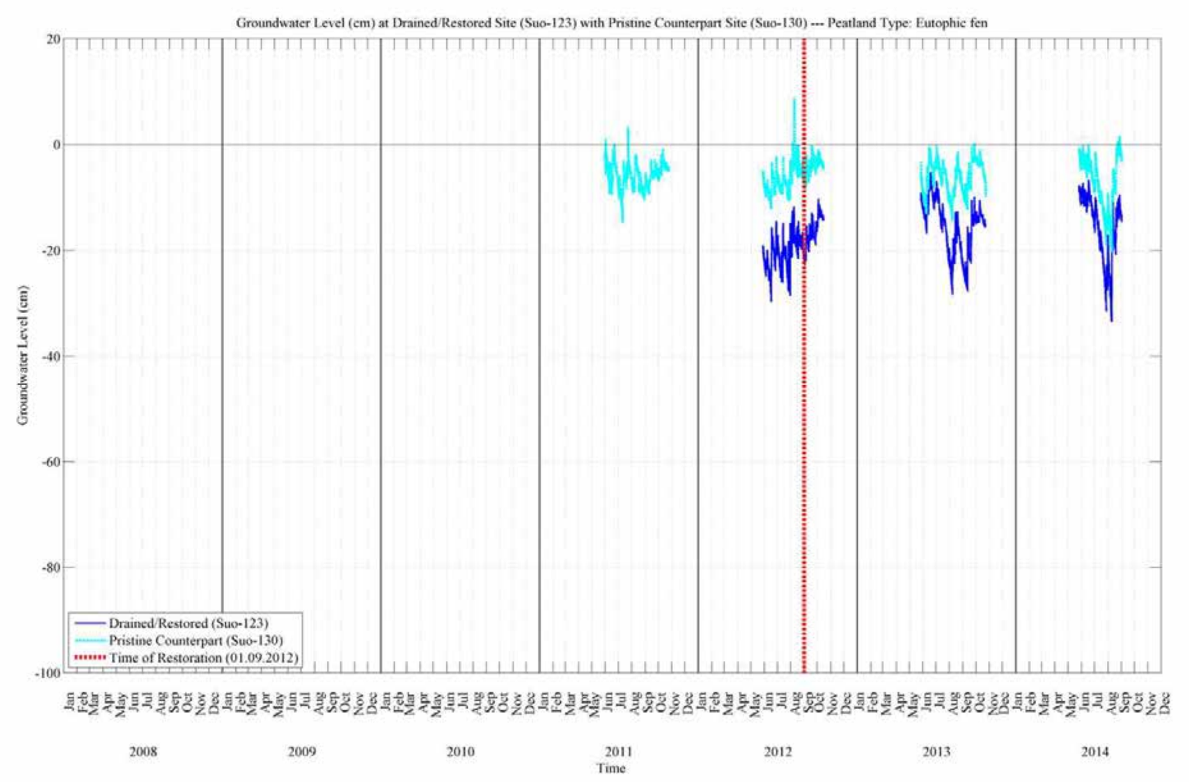

Groundwater Level (cm) at Drained/Restored Site (Suo-105) with Pristine Counterpart Site (Suo-116) --- Peatland Type: Mesotrophic fen
Groundwater Level (cm)
Drained/Restored (Suo-105)
Pristine Counterpart (Suo-116)
Time of Restoration (01.09.2011)
2008
2009
2010
2011
2012
2013
2014
Time


Groundwater Level (cm) at Drained/Restored Site (Suo-107) with Pristine Counterpart Site (Suo-117) --- Peatland Type: Mesotrophic fen
Groundwater Level (cm)
Drained/Restored (Suo-107)
Pristine Counterpart (Suo-117)
Time of Restoration (01.10.2009)
2008
2009
2010
2011
2012
2013
2014
Time

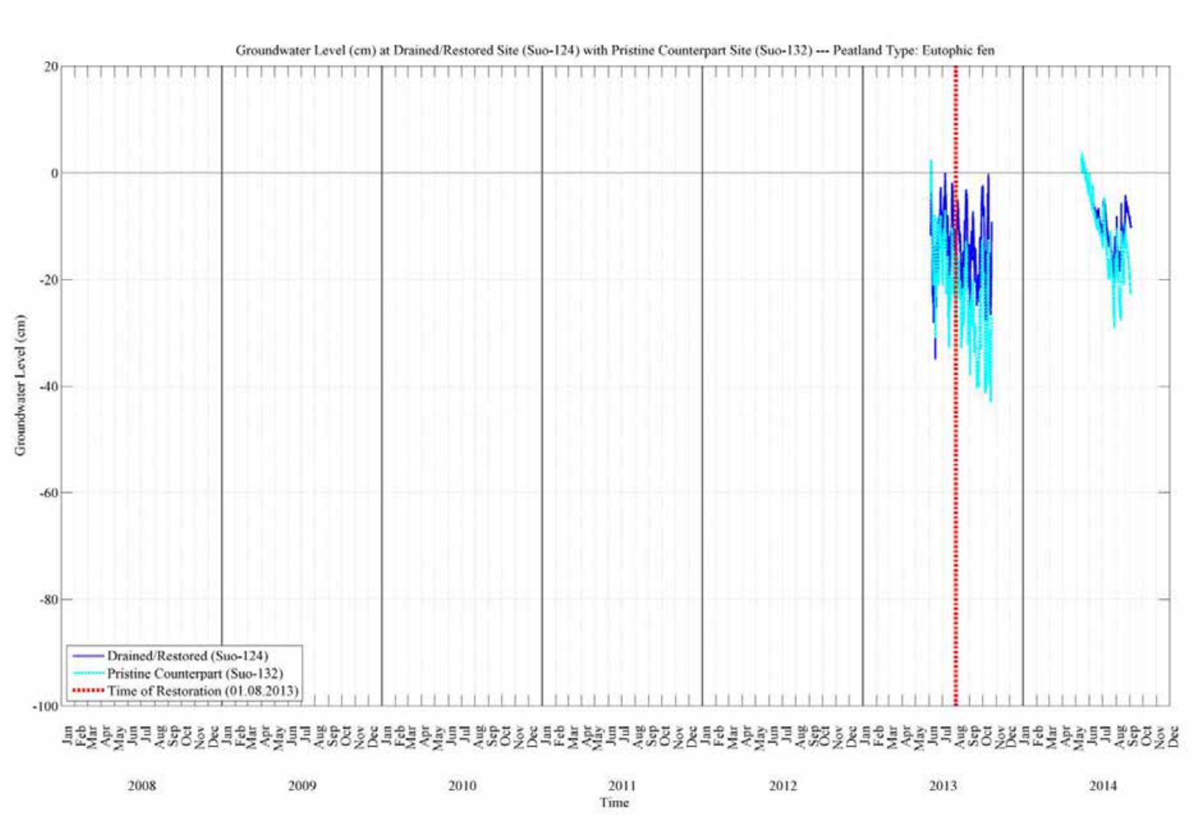

Groundwater Level (cm) at Drained/Restored Site (Suo-108) with Pristine Counterpart Site (Suo-118) --- Peatland Type: Mesotrophic fen
Groundwater Level (cm)
Drained/Restored (Suo-108)
Pristine Counterpart (Suo-118)
Time of Restoration (01.09.2012)
2008
2009
2010
2011
2012
2013
2014
Time



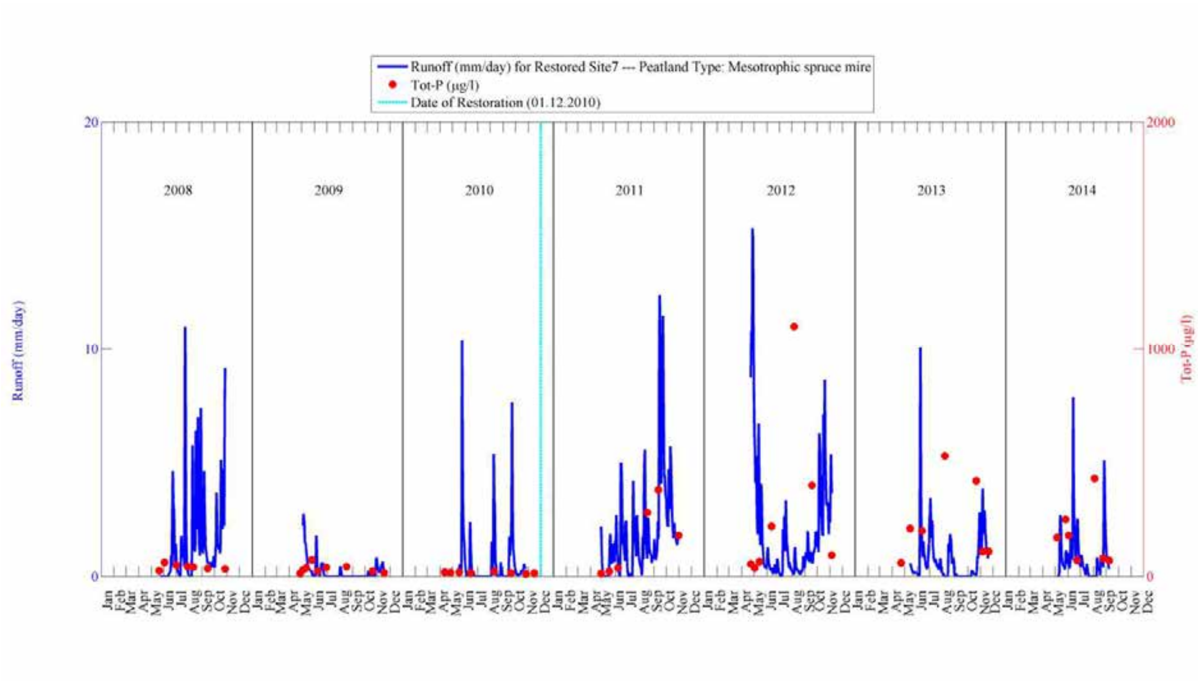
Groundwater Level (cm) at Drained/Restored Site (Suo-121) with Pristine Counterpart Site (Suo-128) --- Peatland Type: Eutophic fen
Groundwater Level (cm)
20
0
-20
-40
-60
-80
-100
Drained/Restored (Suo-121)
Pristine Counterpart (Suo-128)
Time of Restoration (01.09.2011)
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
2008
2009
2010
2011
2012
2013
2014
Time

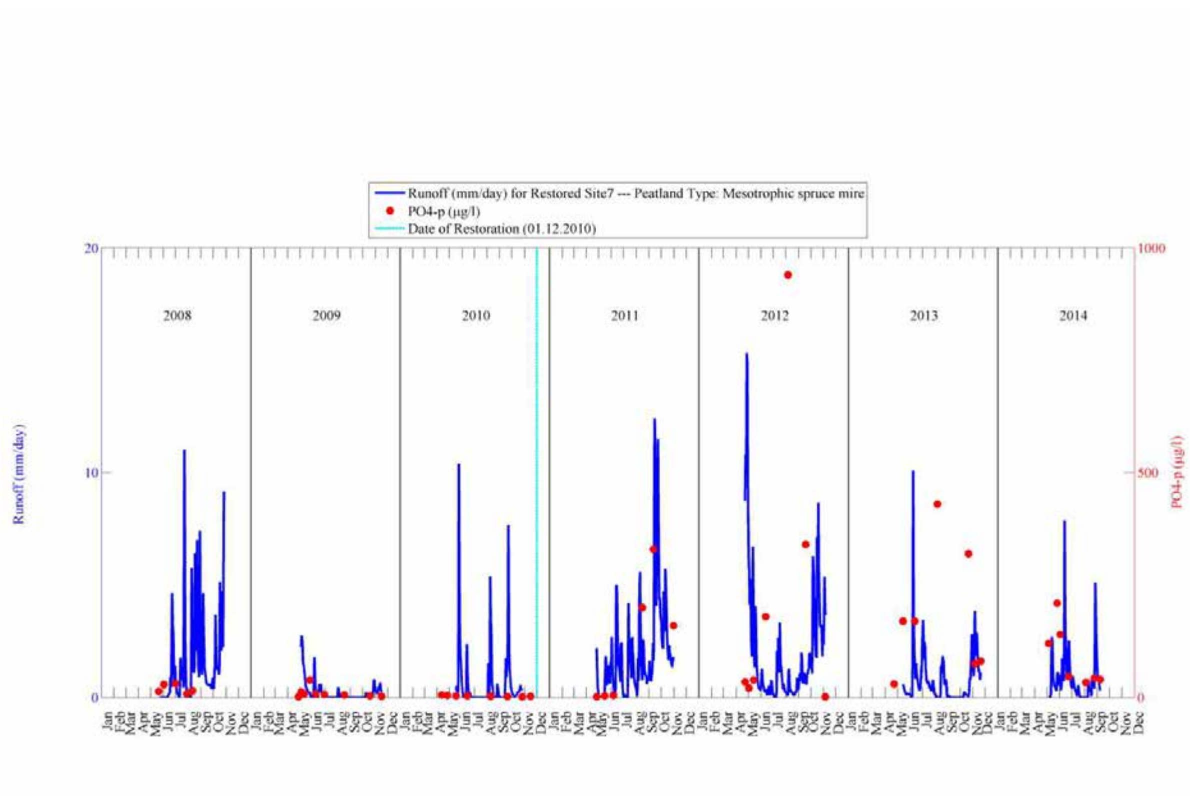


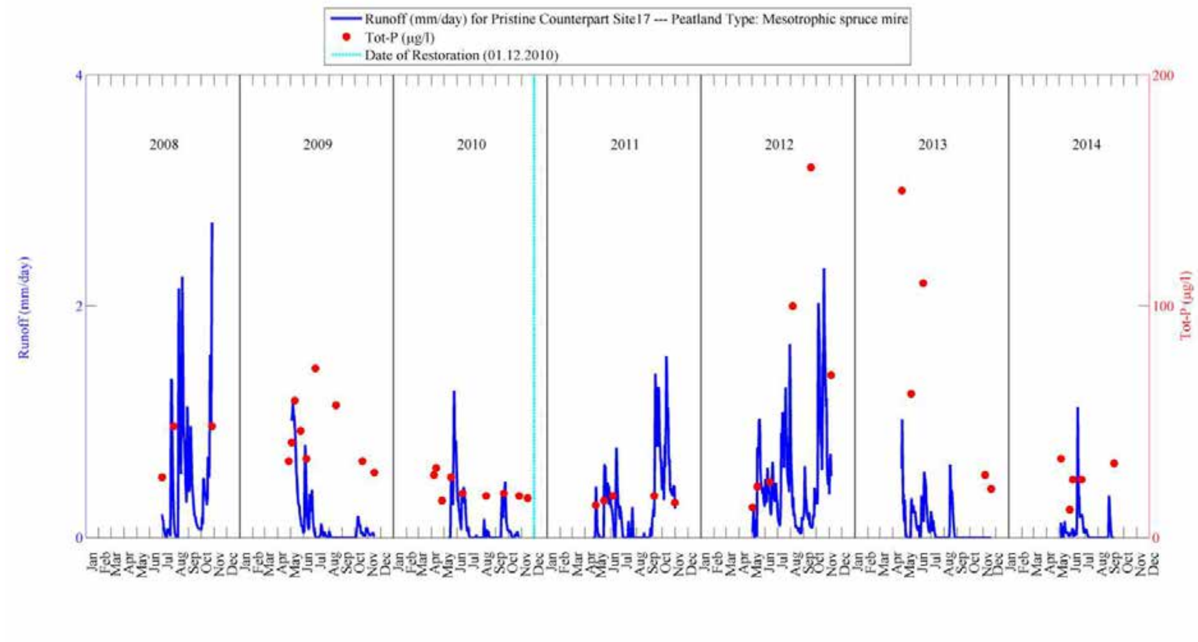
Groundwater Level (cm) at Drained/Restored Site (Suo-123) with Pristine Counterpart Site (Suo-130) --- Peatland Type: Eutophic fen
Groundwater Level (cm)
20
0
-20
-40
-60
-80
-100
Drained/Restored (Suo-123)
Pristine Counterpart (Suo-130)
Time of Restoration (01.09.2012)
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
2008
2009
2010
2011
2012
2013
2014
Time


Groundwater Level (cm) at Drained/Restored Site (Suo-124) with Pristine Counterpart Site (Suo-132) --- Peatland Type: Eutophic fen
Groundwater Level (cm)
Time
2008
2009
2010
2011
2012
2013
2014
Drained/Restored (Suo-124)
Pristine Counterpart (Suo-132)
Time of Restoration (01.08.2013)

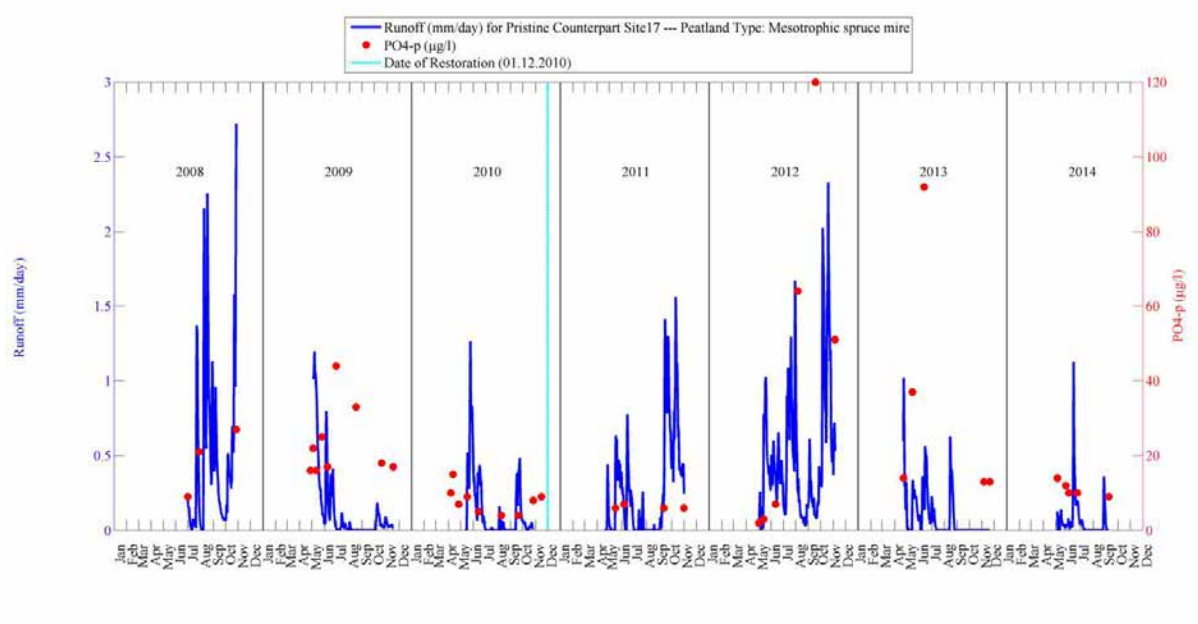
Appendix 3: Runoff (mm d^{-1}) and phosphorus (P_{total} and PO_4-P) of sites with continuous discharge (2008-2014).



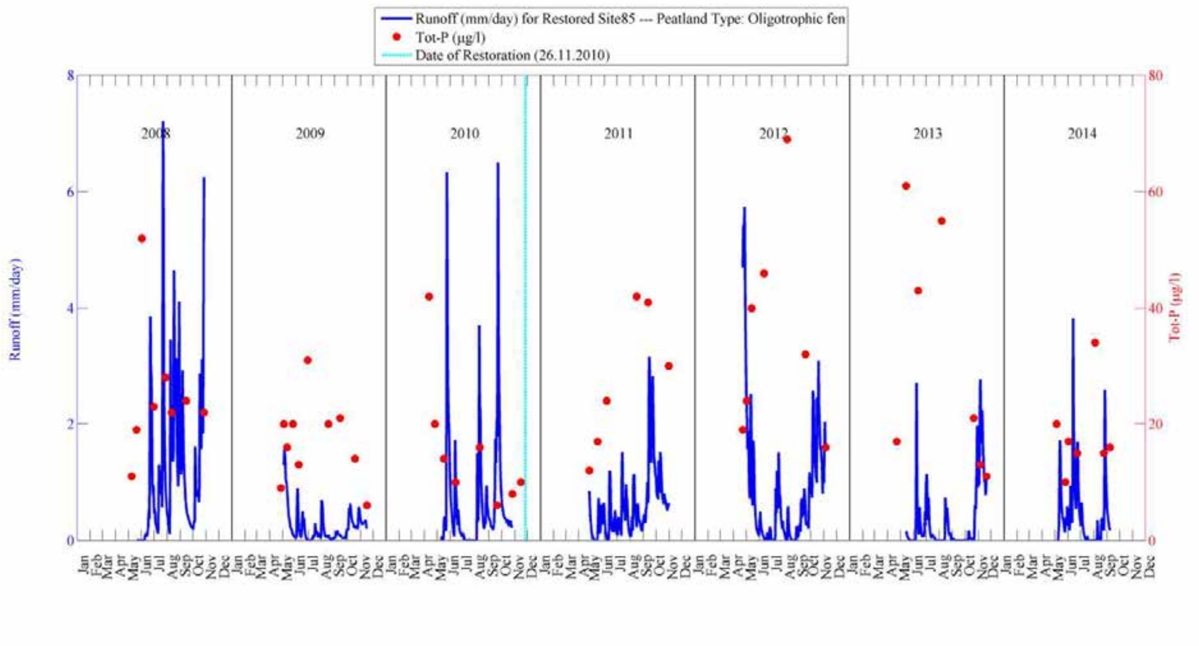


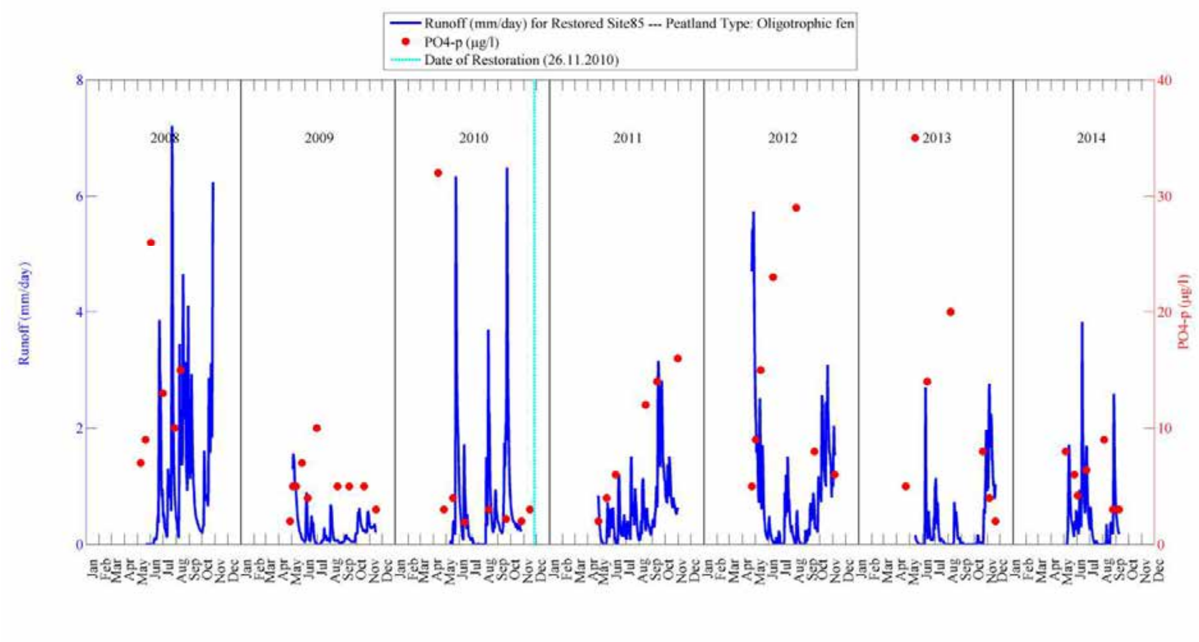


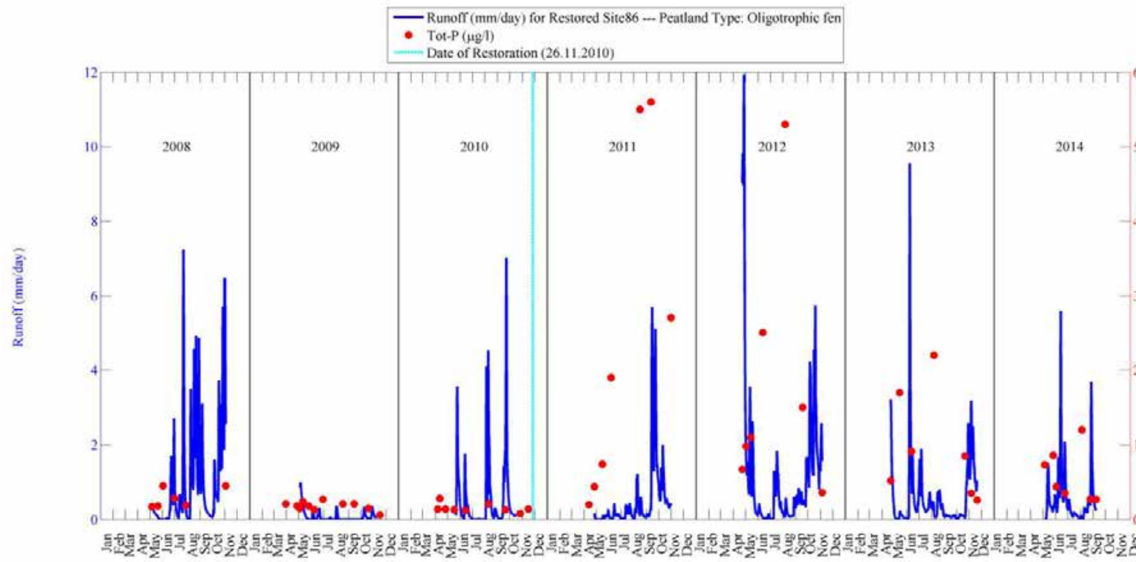
Runoff (mm/day) for Pristine Counterpart Site17 --- Peatland Type: Mesotrophic spruce mire
Tot-P (µg/l)
Date of Restoration (01.12.2010)
Runoff (mm/day)
Tot-P (µg/l)
2008
2009
2010
2011
2012
2013
2014

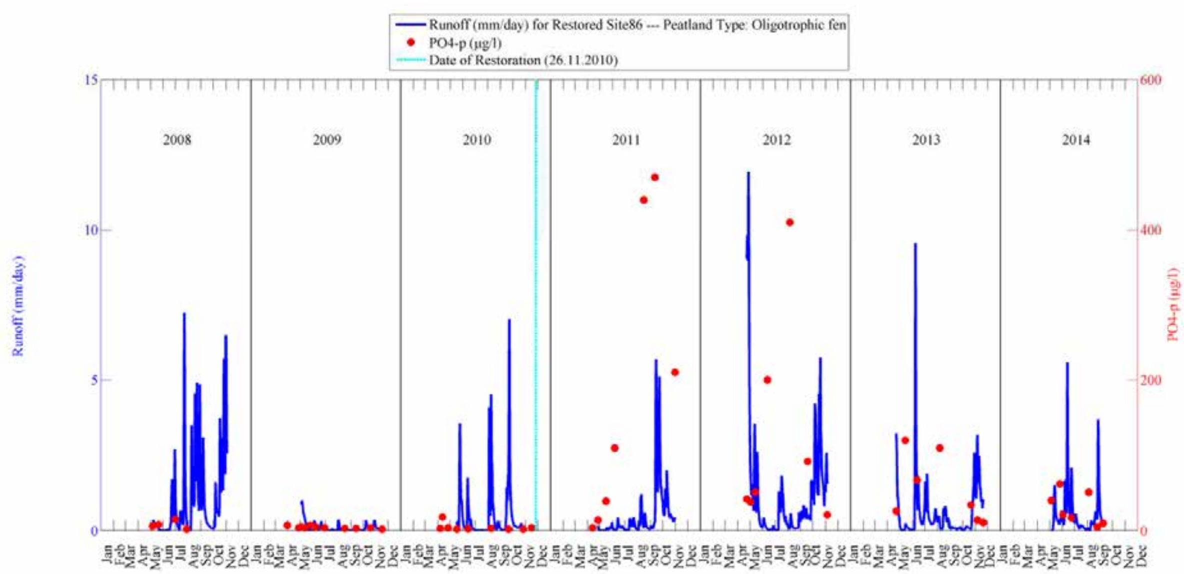


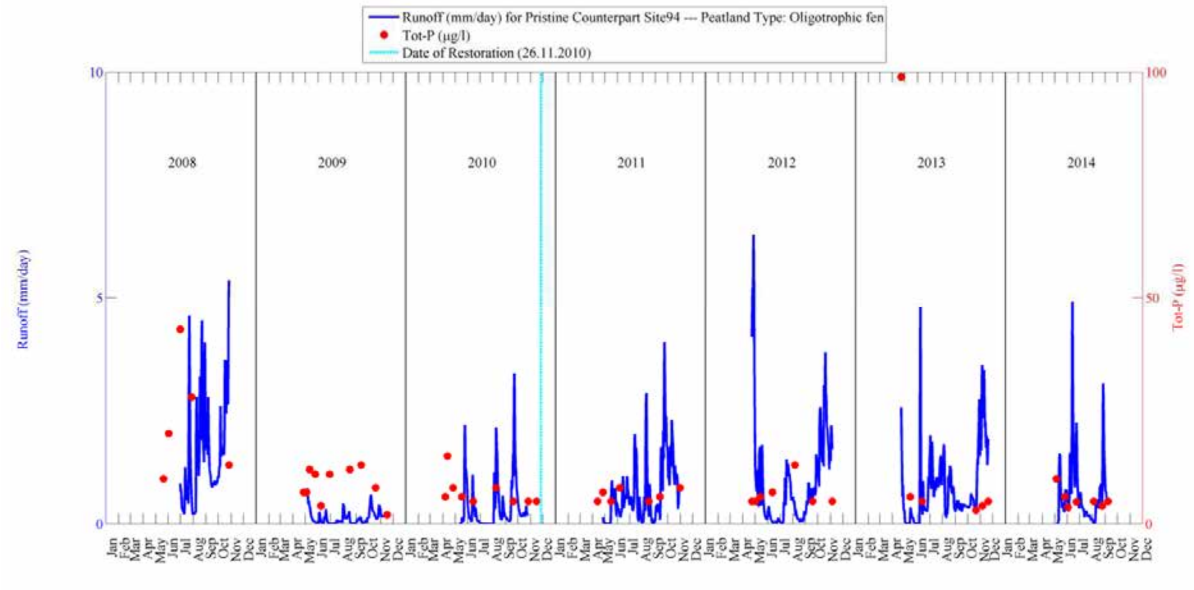
Runoff (mm/day) for Pristine Counterpart Site17 --- Peatland Type: Mesotrophic spruce mire
PO4-p (µg/l)
Date of Restoration (01.12.2010)
Runoff (mm/day)
PO4-p (µg/l)
2008
2009
2010
2011
2012
2013
2014


Runoff (mm/day) for Restored Site85 --- Peatland Type: Oligotrophic fen
Tot-P (µg/l)
Date of Restoration (26.11.2010)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
Tot-P (µg/l)

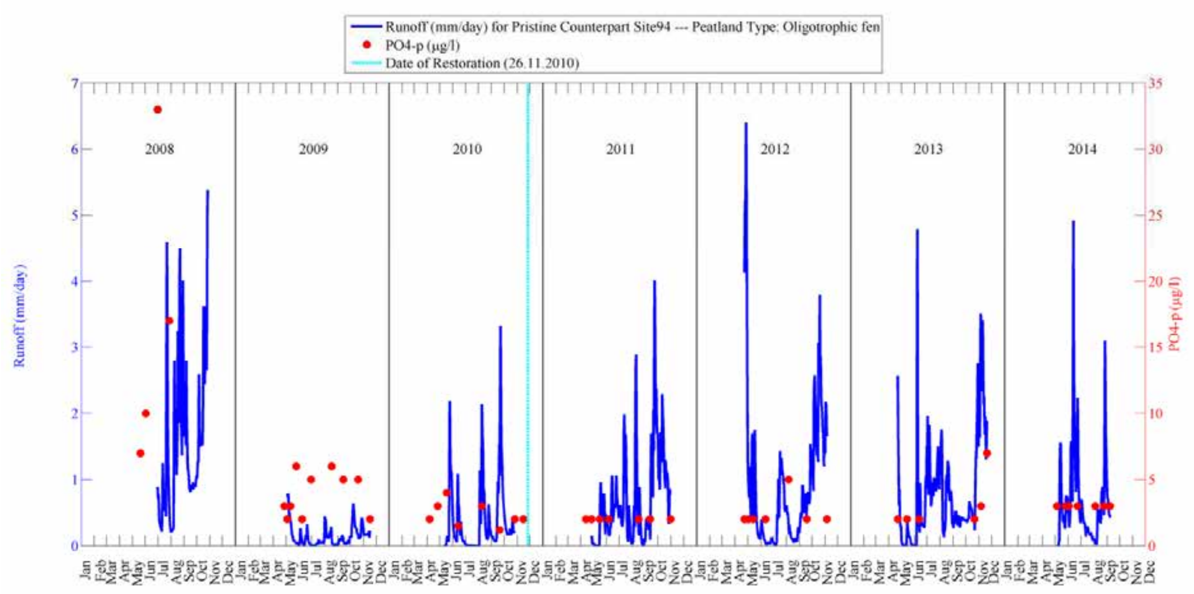

Runoff (mm/day) for Restored Site85 --- Peatland Type: Oligotrophic fen
PO4-p (µg/l)
Date of Restoration (26.11.2010)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
PO4-p (µg/l)


Runoff (mm/day) for Restored Site86 --- Peatland Type: Oligotrophic fen
Tot-P (µg/l)
Date of Restoration (26.11.2010)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
Tot-P (µg/l)

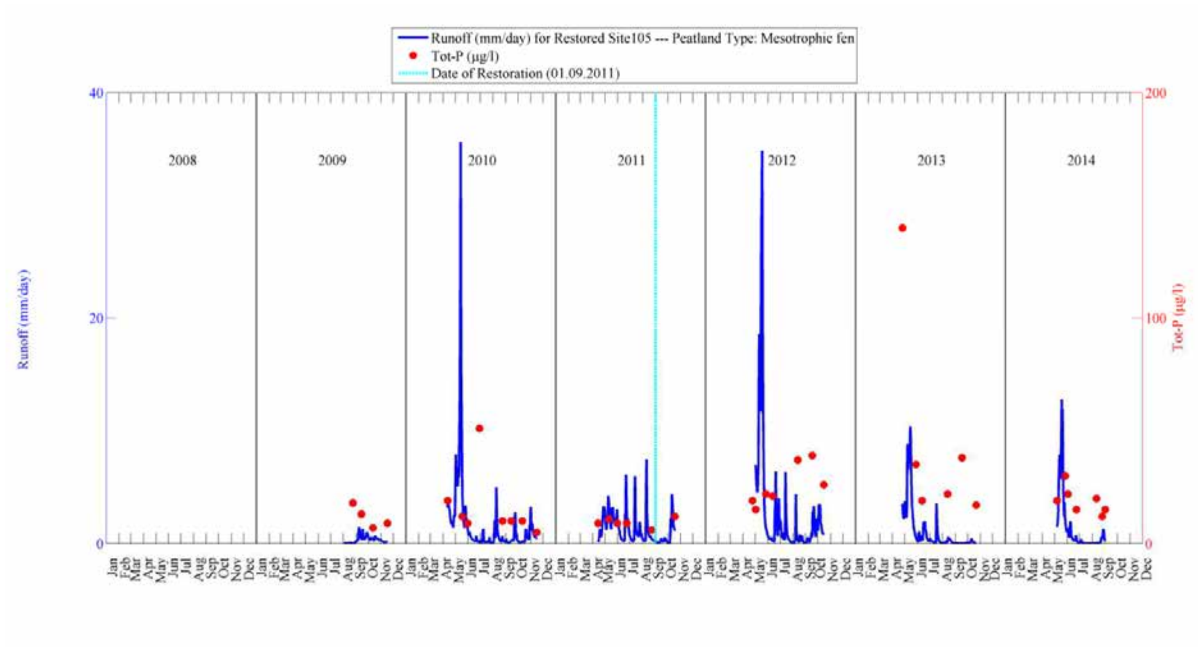

Runoff (mm/day) for Restored Site86 --- Peatland Type: Oligotrophic fen
PO4-p (µg/l)
Date of Restoration (26.11.2010)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
PO4-p (µg/l)

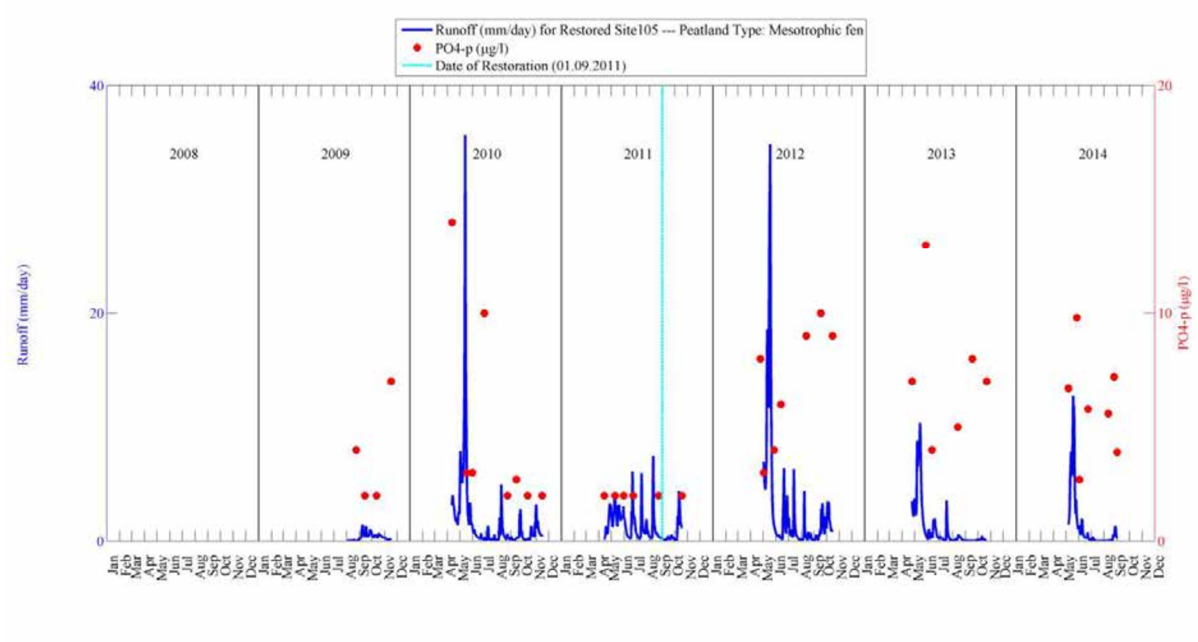


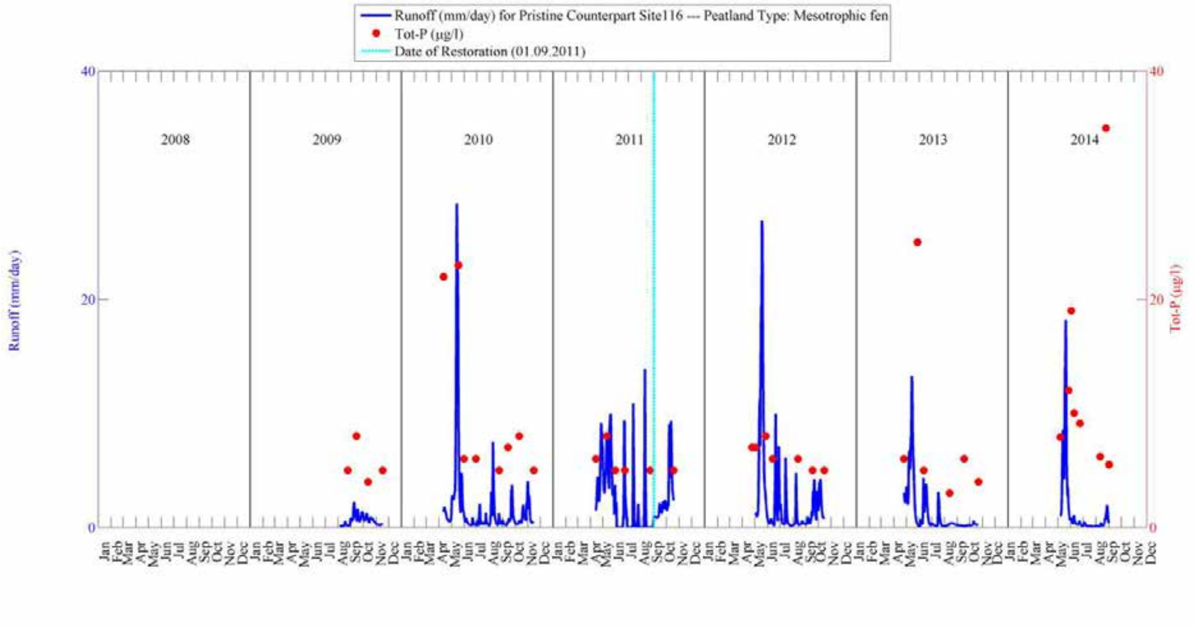
Runoff (mm/day) for Pristine Counterpart Site94 --- Peatland Type: Oligotrophic fen
Tot-P (µg/l)
Date of Restoration (26.11.2010)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
Tot-P (µg/l)

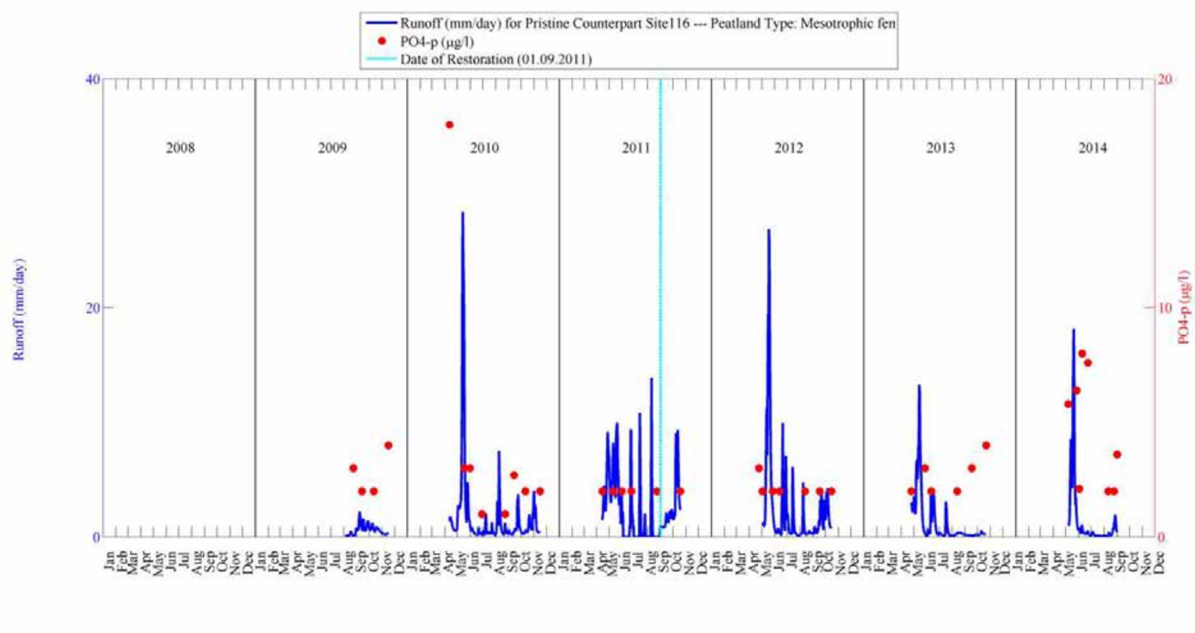


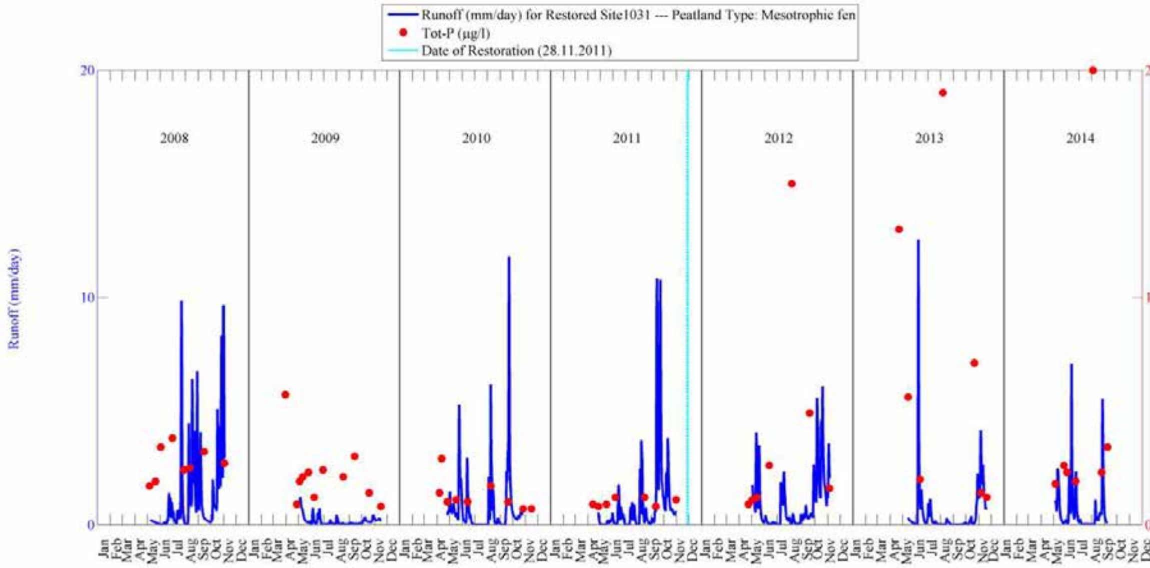
Runoff (mm/day) for Pristine Counterpart Site94 --- Peatland Type: Oligotrophic fen
PO4-p (µg/l)
Date of Restoration (26.11.2010)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
PO4-p (µg/l)


Runoff (mm/day) for Restored Site105 --- Peatland Type: Mesotrophic fen
Tot-P (µg/l)
Date of Restoration (01.09.2011)
Runoff (mm/day)
Tot-P (µg/l)
2008
2009
2010
2011
2012
2013
2014

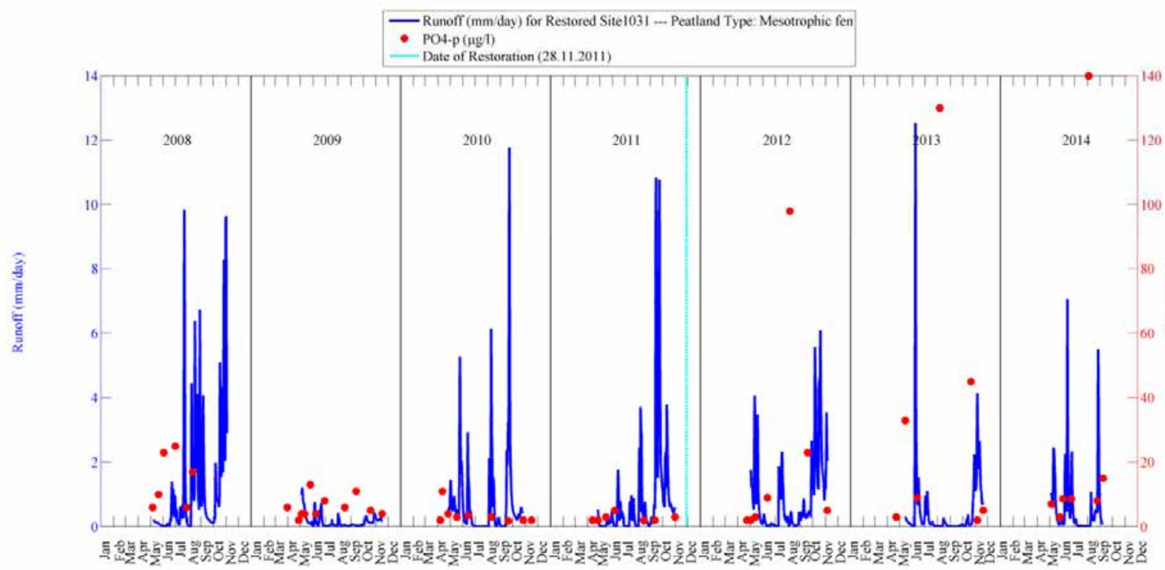

Runoff (mm/day) for Restored Site105 --- Peatland Type: Mesotrophic fen
PO4-p (µg/l)
Date of Restoration (01.09.2011)
Runoff (mm/day)
PO4-p (µg/l)
2008
2009
2010
2011
2012
2013
2014


Runoff (mm/day) for Pristine Counterpart Site116 --- Peatland Type: Mesotrophic fen
Tot-P (µg/l)
Date of Restoration (01.09.2011)
Runoff (mm/day)
Tot-P (µg/l)
2008
2009
2010
2011
2012
2013
2014

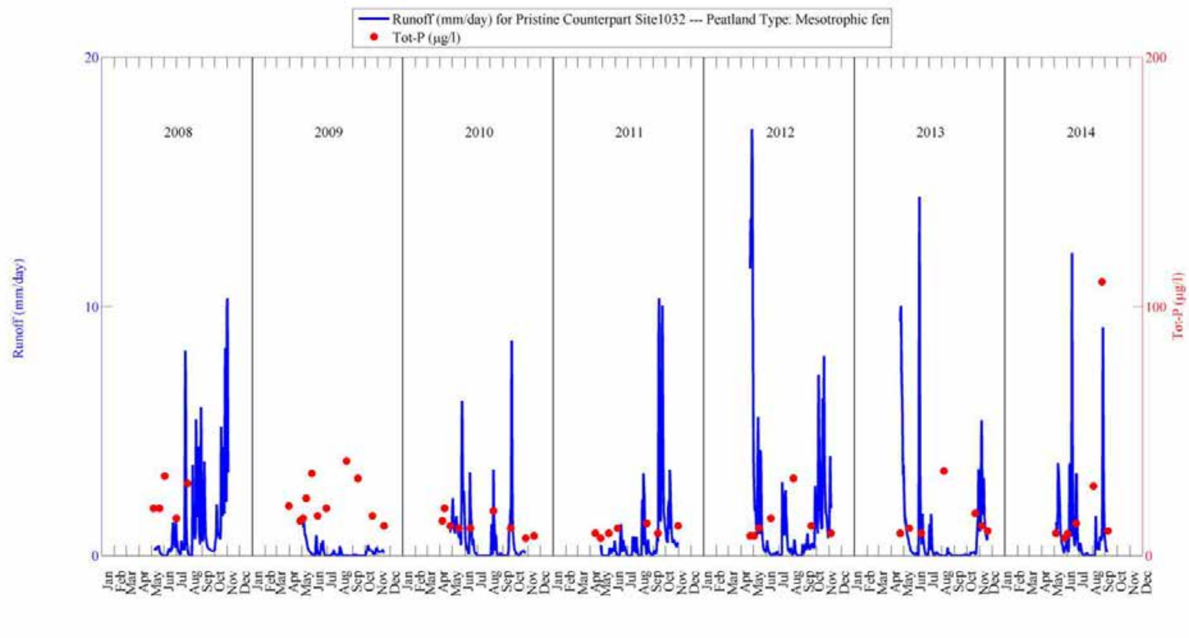

Runoff (mm/day) for Pristine Counterpart Site116 --- Peatland Type: Mesotrophic fen
PO4-p (µg/l)
Date of Restoration (01.09.2011)
Runoff (mm/day)
PO4-p (µg/l)
2008
2009
2010
2011
2012
2013
2014



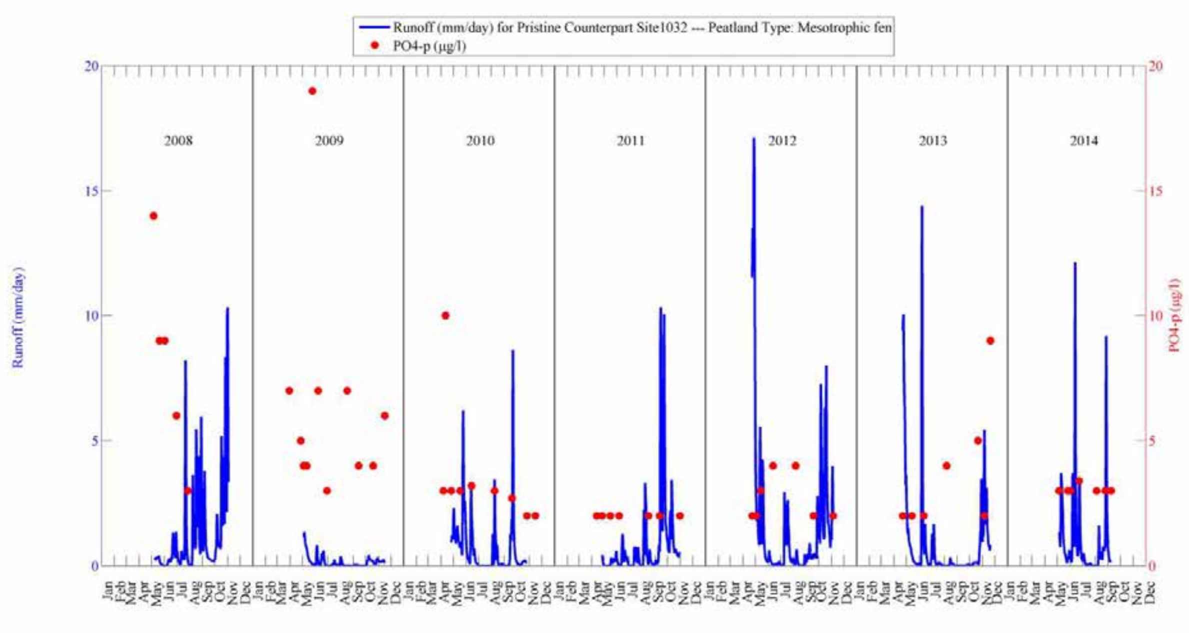
Runoff (mm/day) for Restored Site1031 --- Peatland Type: Mesotrophic fen
Tot-P (µg/l)
Date of Restoration (28.11.2011)
Runoff (mm/day)
Tot-P (µg/l)
2008
2009
2010
2011
2012
2013
2014
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec



Runoff (mm/day) for Restored Site1031 --- Peatland Type: Mesotrophic fen
PO4-p (µg/l)
Date of Restoration (28.11.2011)
Runoff (mm/day)
PO4-p (µg/l)
2008
2009
2010
2011
2012
2013
2014
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

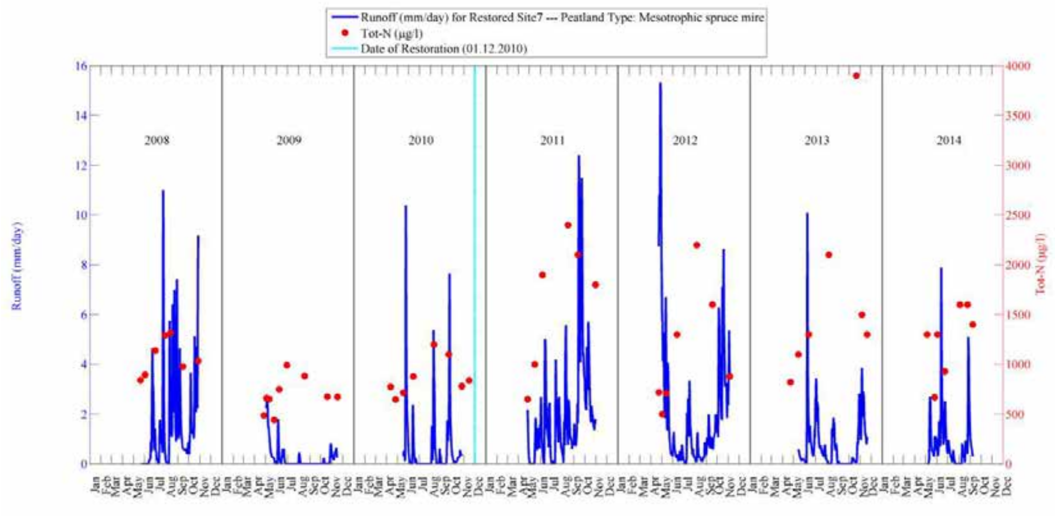


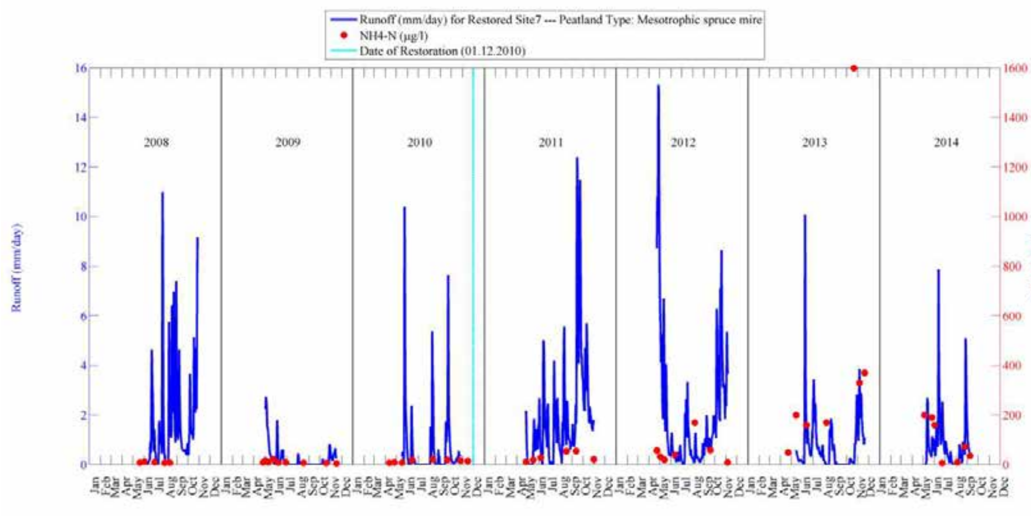
Runoff (mm/day) for Pristine Counterpart Site1032 --- Peatland Type: Mesotrophic fen
Tot-P (µg/l)
Runoff (mm/day)
Tot-P (µg/l)
2008
2009
2010
2011
2012
2013
2014

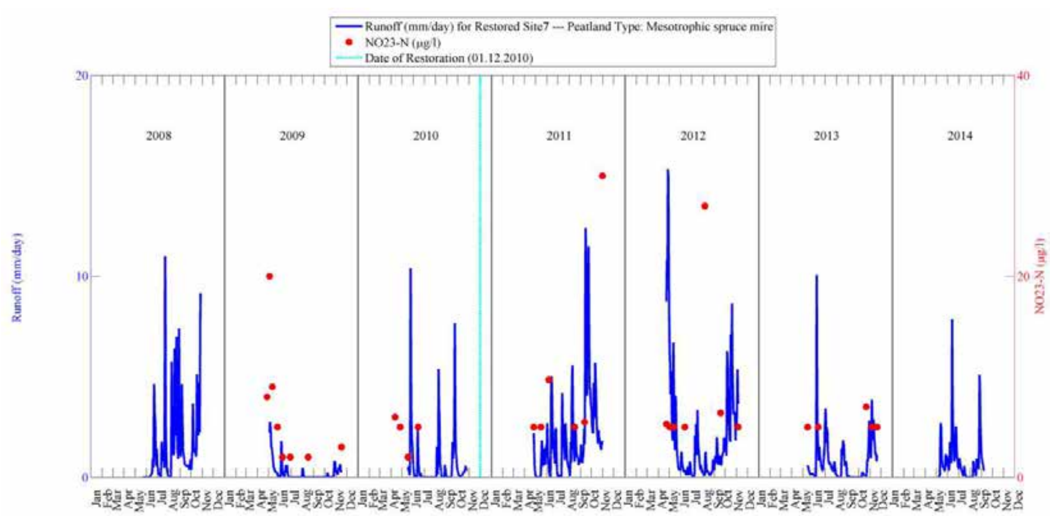


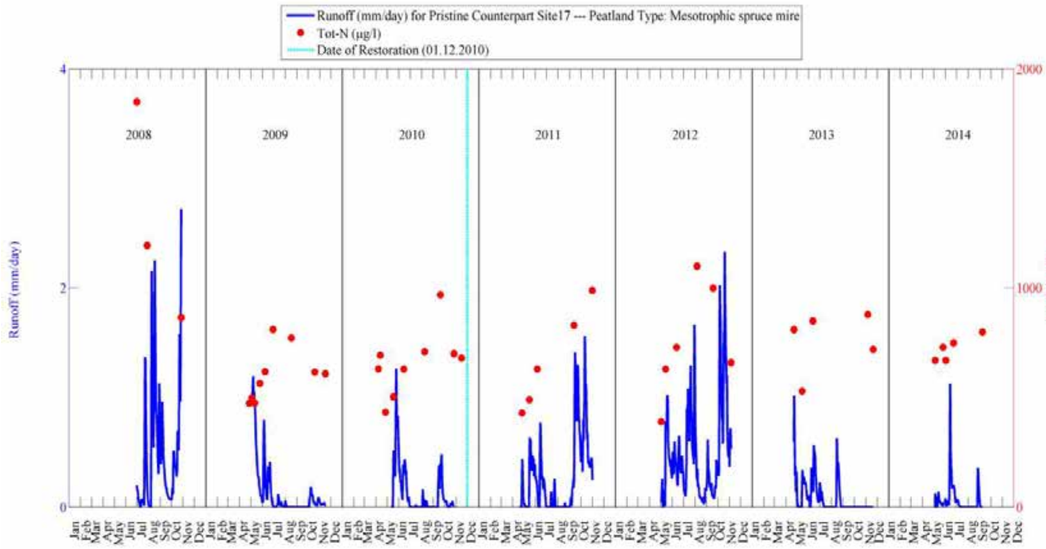
Runoff (mm/day) for Pristine Counterpart Site1032 --- Peatland Type: Mesotrophic fen
PO4-p (µg/l)
Runoff (mm/day)
PO4-p (µg/l)
2008
2009
2010
2011
2012
2013
2014

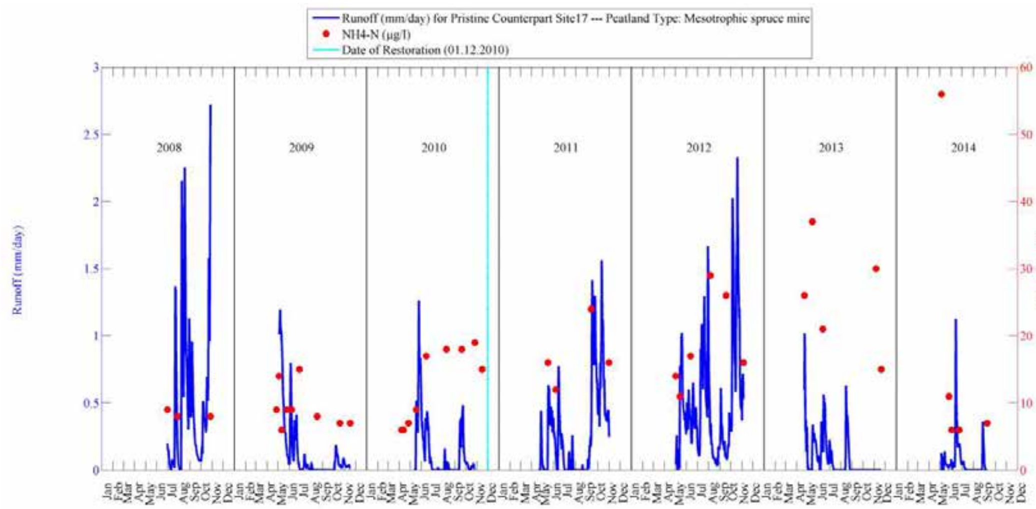
Appendix 4: Runoff (mm d^{-1}) and nitrogen concentrations (N_{total}, NH_4-N and NO_{2+3}-N) with continuous discharge monitoring (2008-2014).

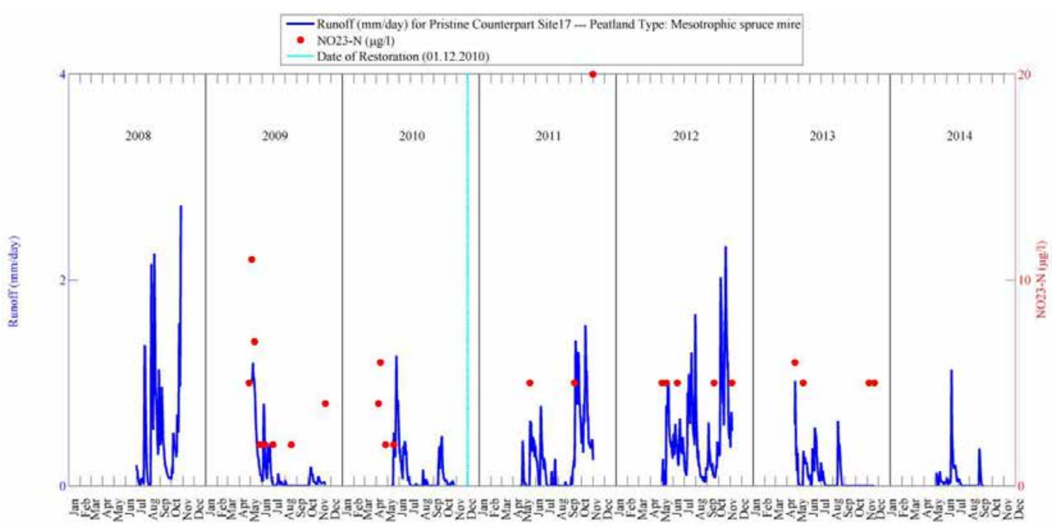


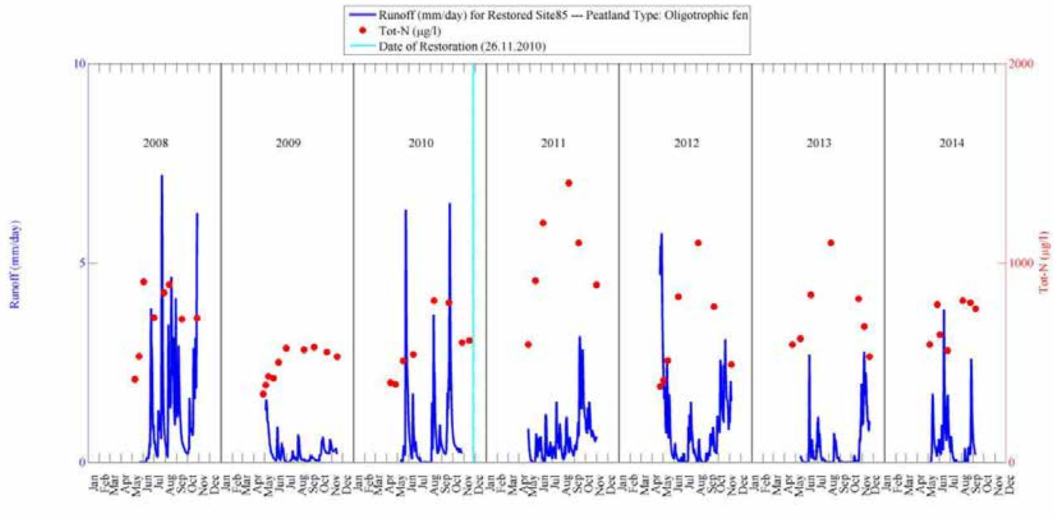


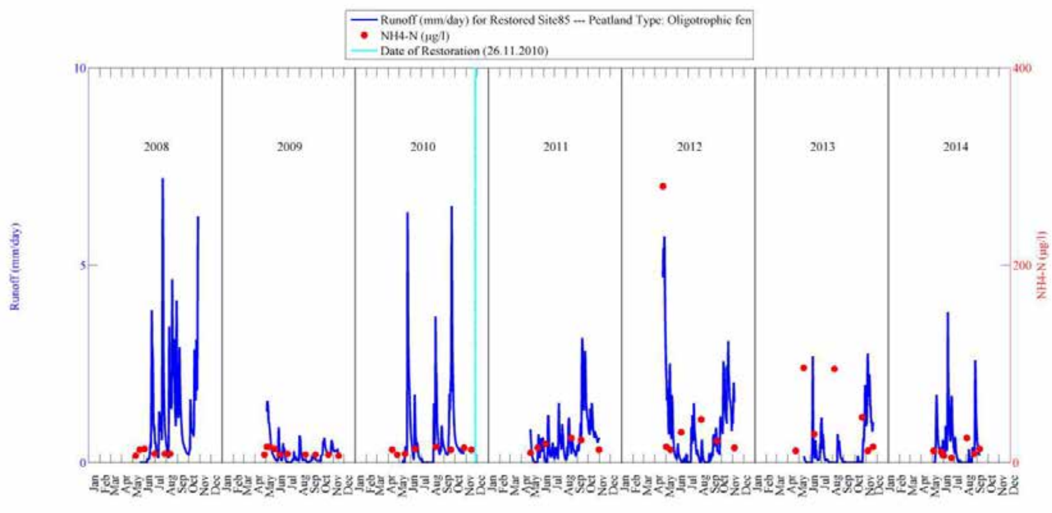


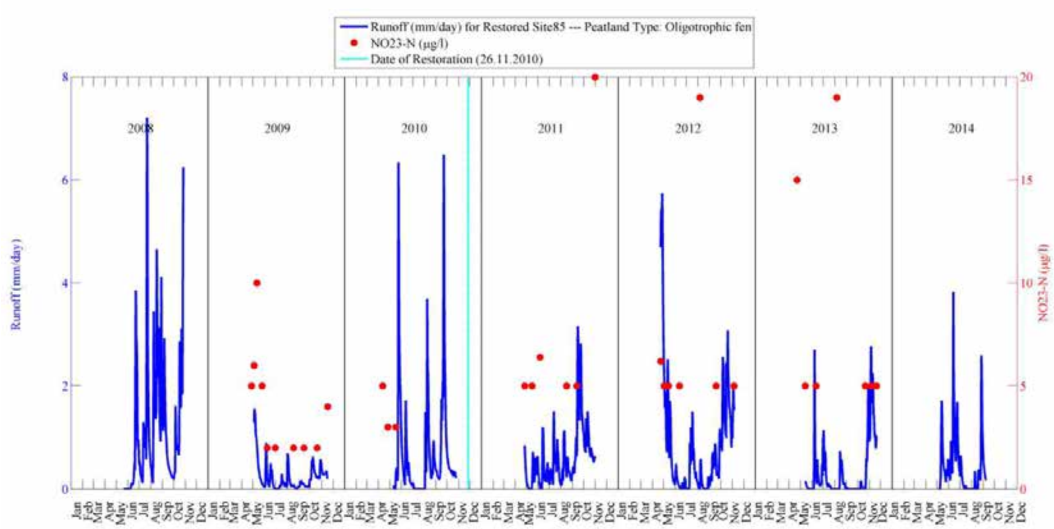

Runoff (mm/day) for Pristine Counterpart Site17 --- Peatland Type: Mesotrophic spruce mire
Tot-N (µg/l)
Date of Restoration (01.12.2010)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
Tot-N (µg/l)
0
2
4
0
1000
2000
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

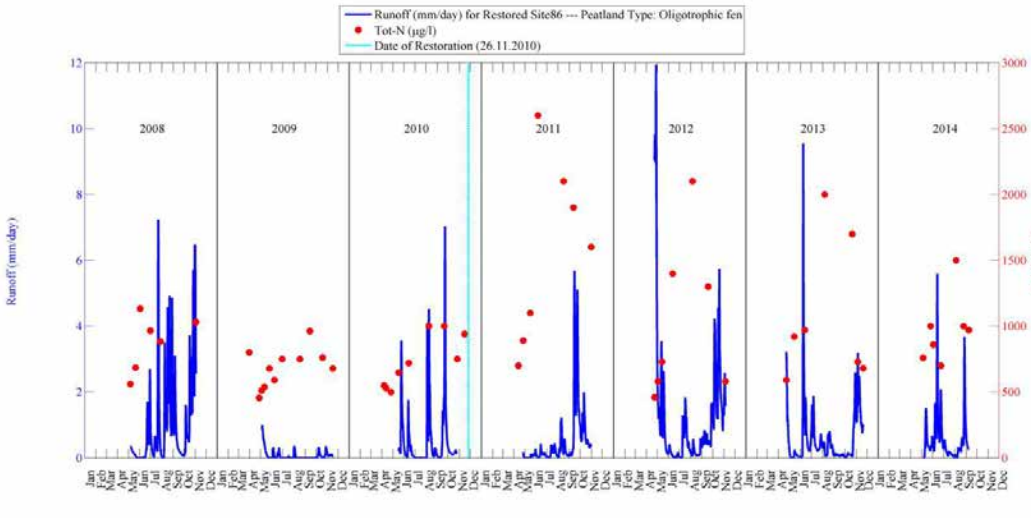

Runoff (mm/day) for Pristine Counterpart Site17 --- Peatland Type: Mesotrophic spruce mire
NH4-N (µg/l)
Date of Restoration (01.12.2010)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
NH4-N (µg/l)
0
0.5
1
1.5
2
2.5
3
0
10
20
30
40
50
60
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

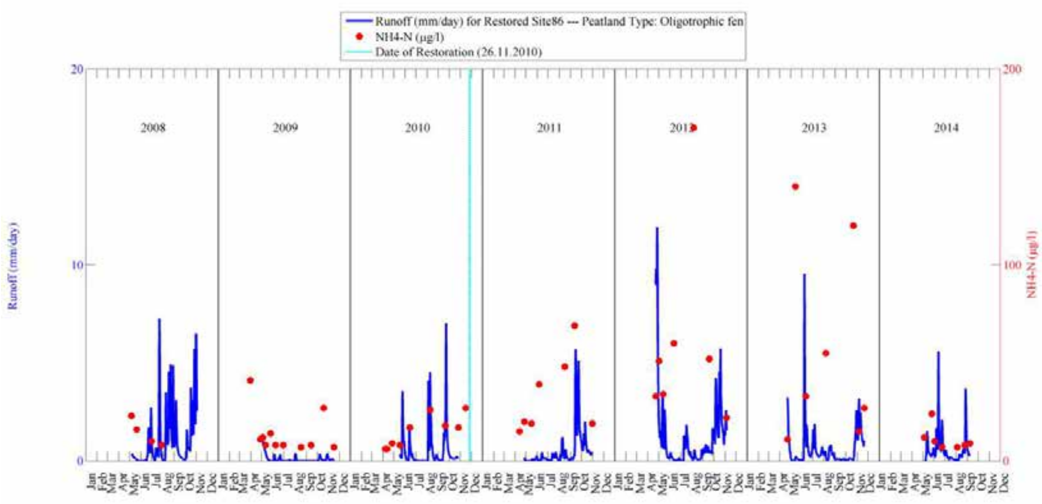

Runoff (mm/day) for Pristine Counterpart Site17 --- Peatland Type: Mesotrophic spruce mire
NO23-N (µg/l)
Date of Restoration (01.12.2010)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
NO23-N (µg/l)
0
2
4
0
10
20
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

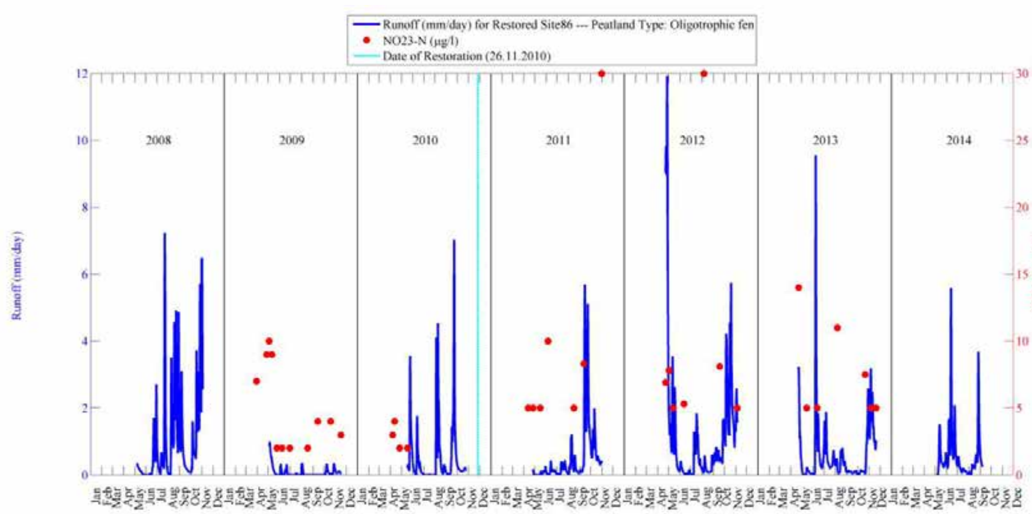

Runoff (mm/day) for Restored Site85 --- Peatland Type: Oligotrophic fen
Tot-N (µg/l)
Date of Restoration (26.11.2010)
Runoff (mm/day)
Tot-N (µg/l)
2008
2009
2010
2011
2012
2013
2014

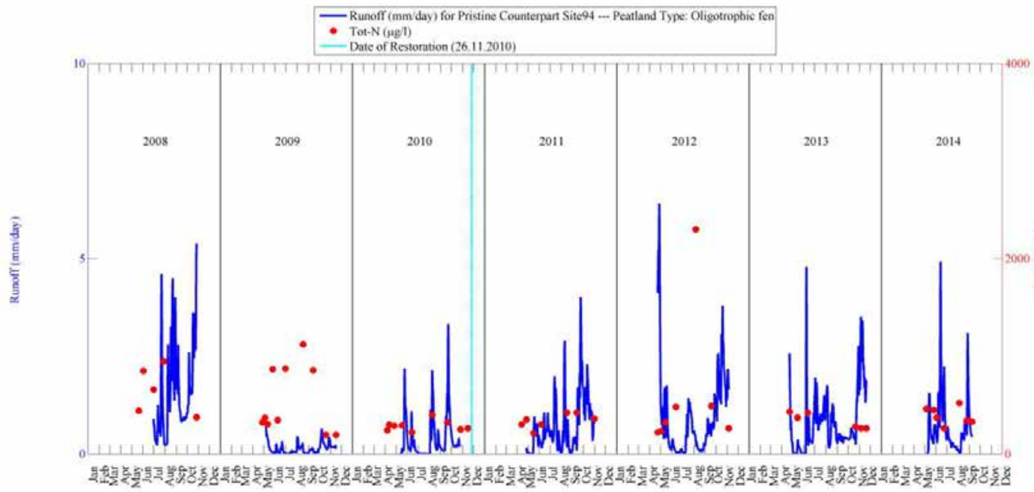

Runoff (mm/day) for Restored Site85 --- Peatland Type: Oligotrophic fen
NH4-N (µg/l)
Date of Restoration (26.11.2010)
Runoff (mm/day)
NH4-N (µg/l)
2008
2009
2010
2011
2012
2013
2014


Runoff (mm/day) for Restored Site85 --- Peatland Type: Oligotrophic fen
NO23-N (µg/l)
Date of Restoration (26.11.2010)
Runoff (mm/day)
NO23-N (µg/l)
2008
2009
2010
2011
2012
2013
2014

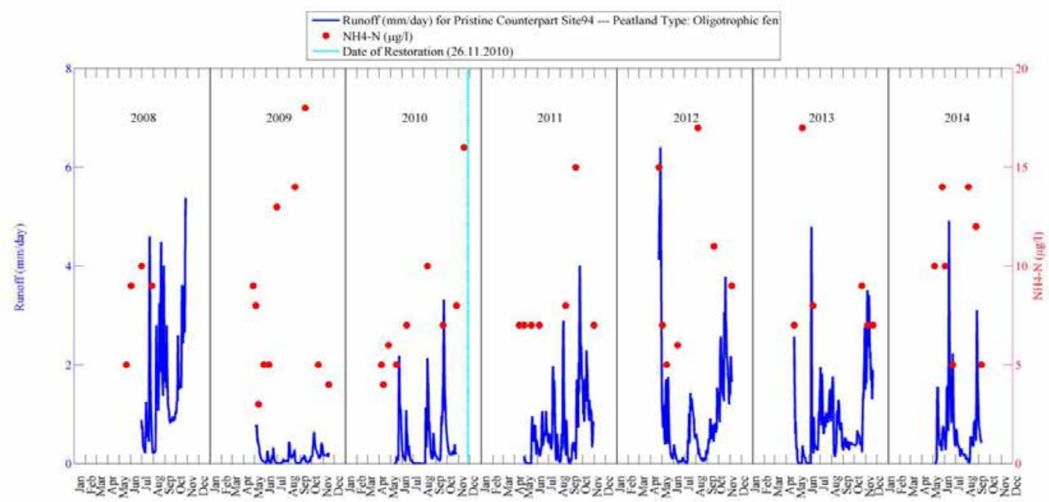

Runoff (mm/day) for Restored Site86 --- Peatland Type: Oligotrophic fen
Tot-N (µg/l)
Date of Restoration (26.11.2010)
Runoff (mm/day)
Tot-N (µg/l)
2008
2009
2010
2011
2012
2013
2014


Runoff (mm/day) for Restored Site86 --- Peatland Type: Oligotrophic fen
NH4-N (µg/l)
Date of Restoration (26.11.2010)
Runoff (mm/day)
NH4-N (µg/l)
2008
2009
2010
2011
2012
2013
2014

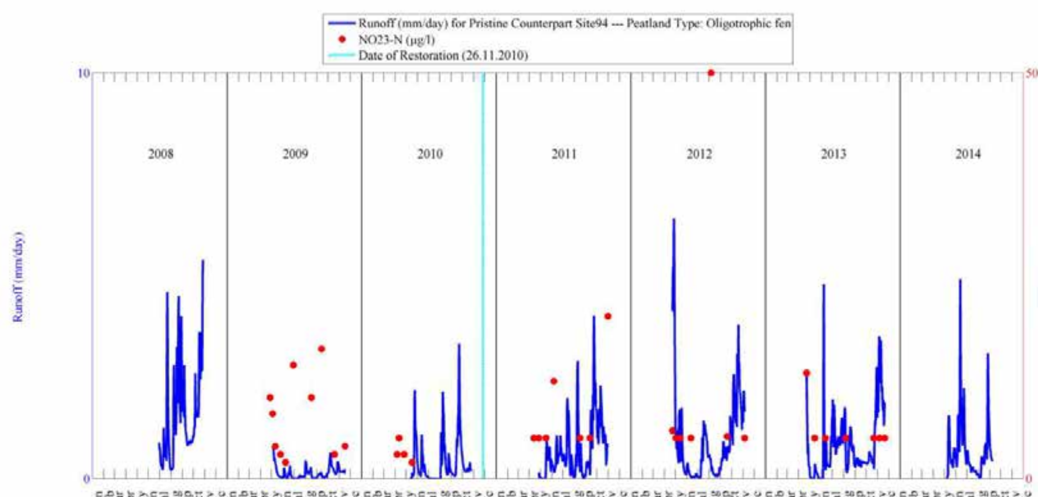

Runoff (mm/day) for Restored Site86 --- Peatland Type: Oligotrophic fen
NO23-N (µg/l)
Date of Restoration (26.11.2010)
Runoff (mm/day)
NO23-N (µg/l)
2008
2009
2010
2011
2012
2013
2014



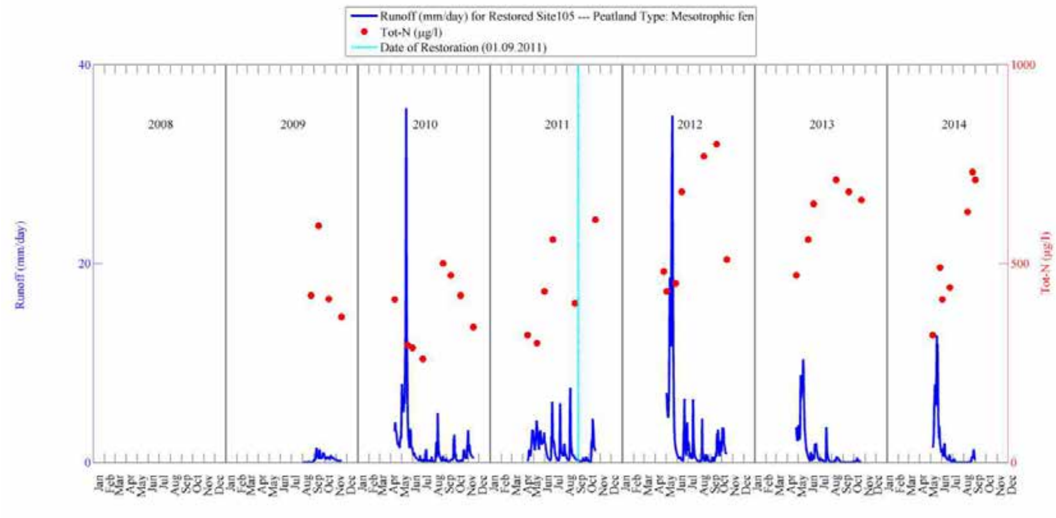
Runoff (mm/day) for Pristine Counterpart Site94 --- Peatland Type: Oligotrophic fen
Tot-N (µg/l)
Date of Restoration (26.11.2010)
Runoff (mm/day)
Tot-N (µg/l)
0
5
10
0
2000
4000
2008
2009
2010
2011
2012
2013
2014

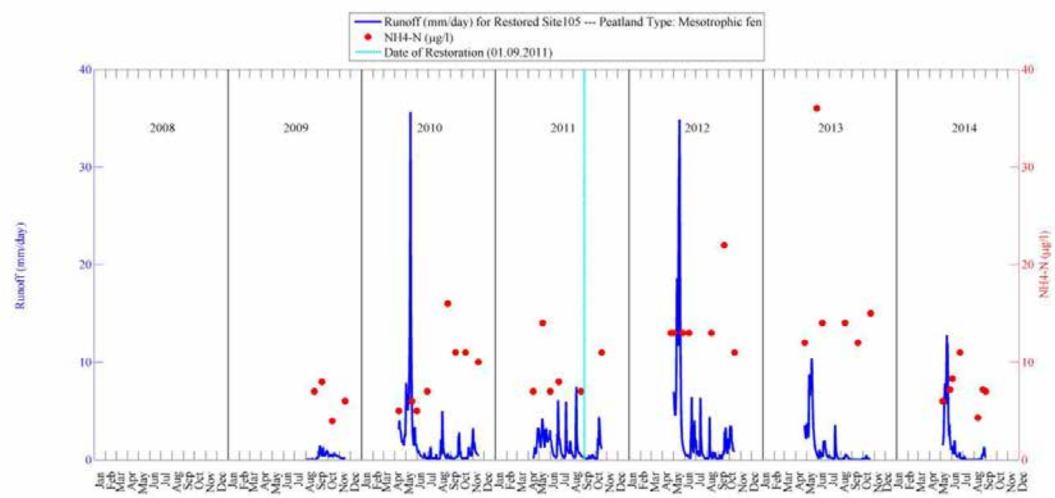


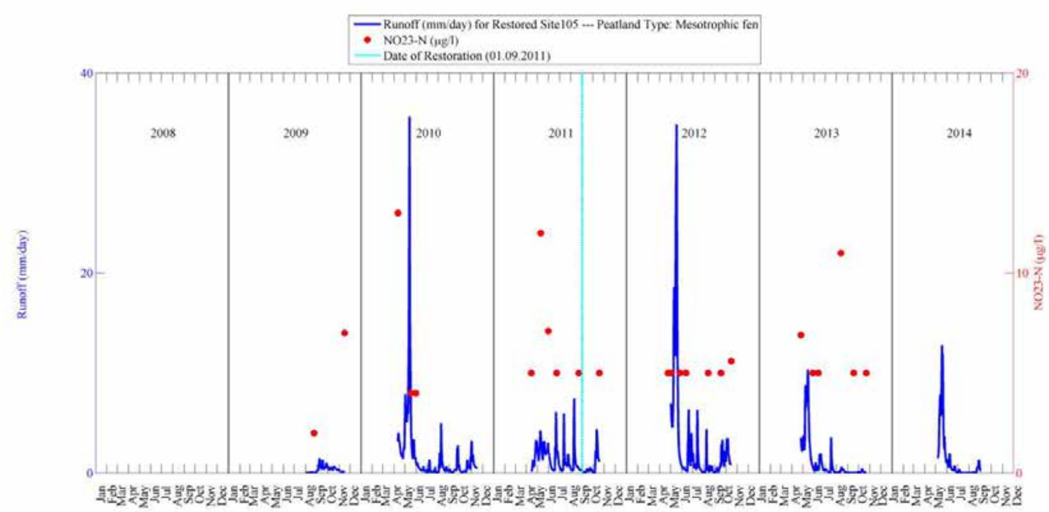
Runoff (mm/day) for Pristine Counterpart Site94 --- Peatland Type: Oligotrophic fen
NH4-N (µg/l)
Date of Restoration (26.11.2010)
Runoff (mm/day)
NH4-N (µg/l)
0
2
4
6
8
0
5
10
15
20
2008
2009
2010
2011
2012
2013
2014

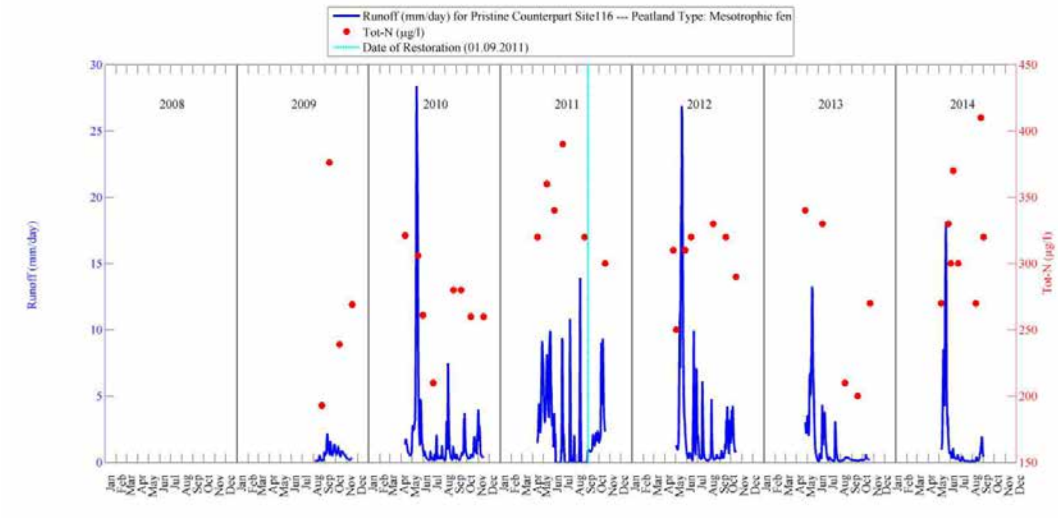


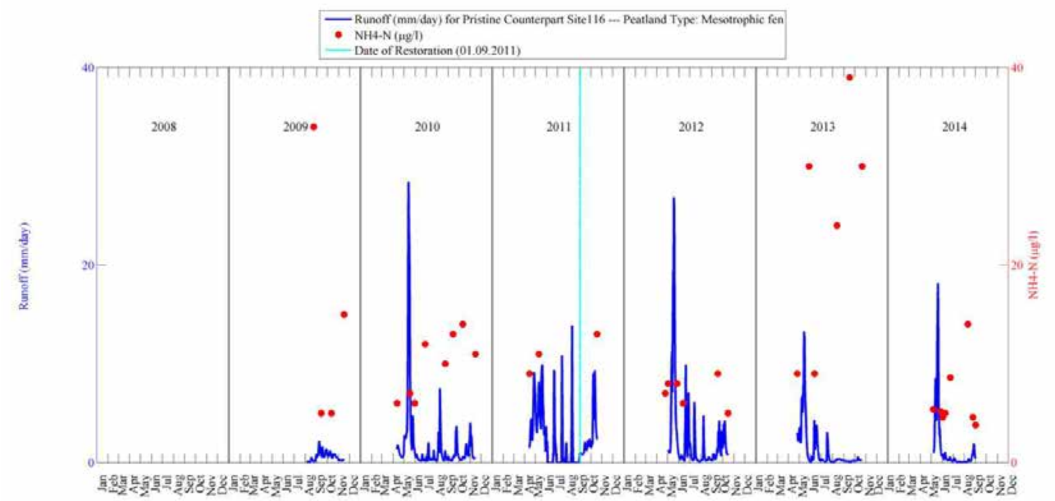
Runoff (mm/day) for Pristine Counterpart Site94 --- Peatland Type: Oligotrophic fen
NO23-N (µg/l)
Date of Restoration (26.11.2010)
Runoff (mm/day)
NO23-N (µg/l)
0
10
0
50
2008
2009
2010
2011
2012
2013
2014

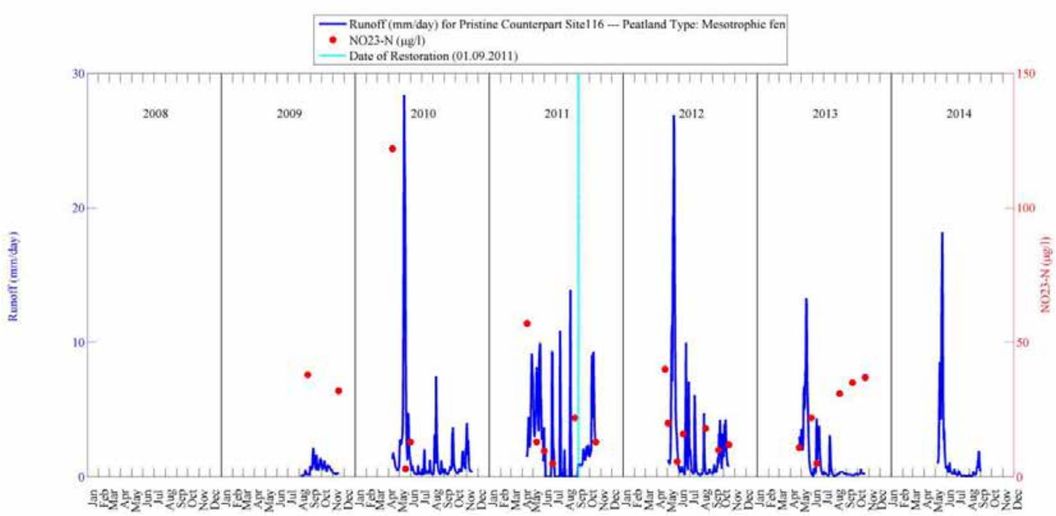

Runoff (mm/day) for Restored Site105 --- Peatland Type: Mesotrophic fen
Tot-N (µg/l)
Date of Restoration (01.09.2011)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
Tot-N (µg/l)

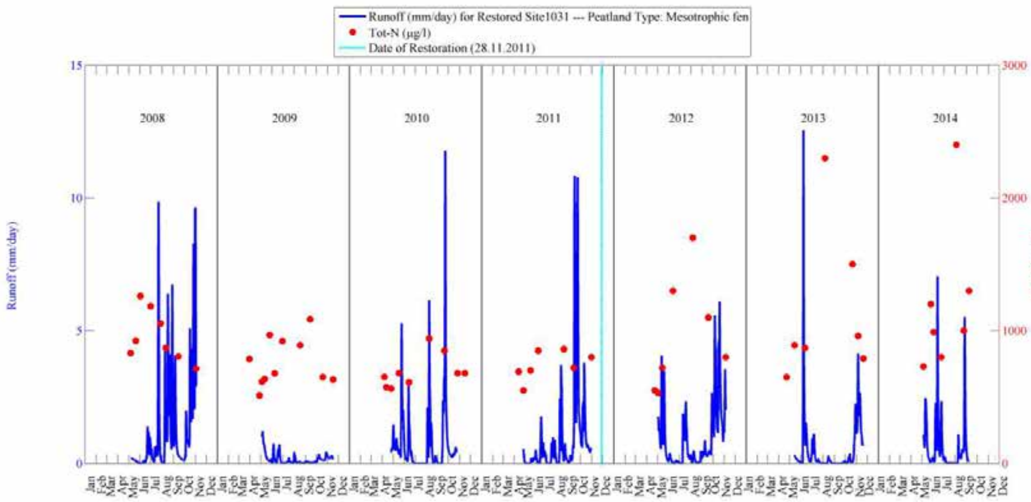

Runoff (mm/day) for Restored Site105 --- Peatland Type: Mesotrophic fen
NH4-N (µg/l)
Date of Restoration (01.09.2011)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
NH4-N (µg/l)

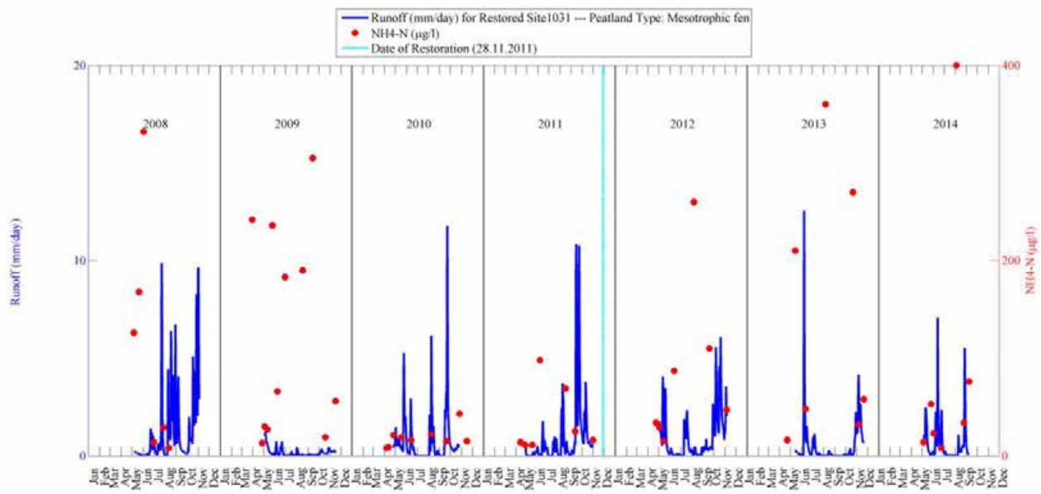

Runoff (mm/day) for Restored Site105 --- Peatland Type: Mesotrophic fen
NO23-N (µg/l)
Date of Restoration (01.09.2011)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
NO23-N (µg/l)

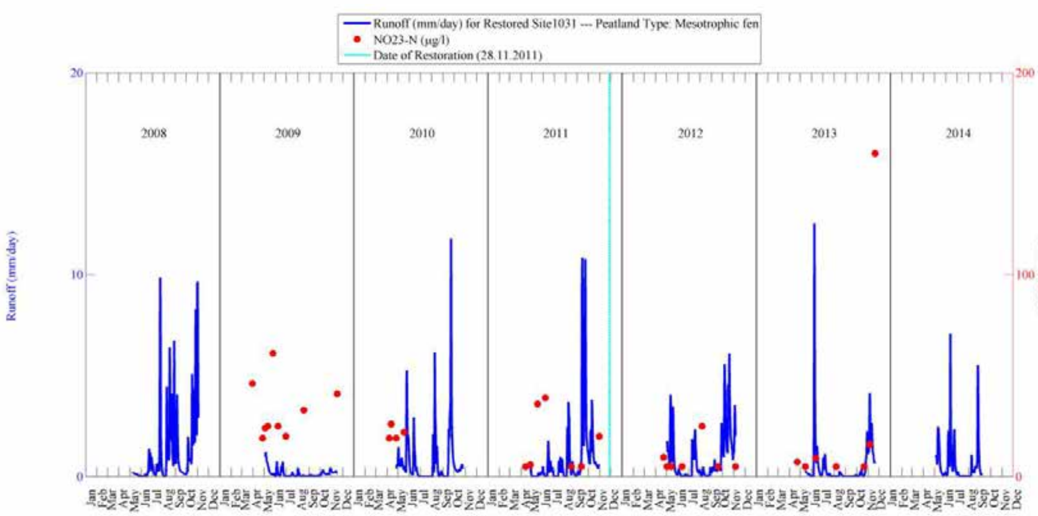

Runoff (mm/day) for Pristine Counterpart Site116 --- Peatland Type: Mesotrophic fen
Tot-N (µg/l)
Date of Restoration (01.09.2011)
Runoff (mm/day)
Tot-N (µg/l)
2008
2009
2010
2011
2012
2013
2014

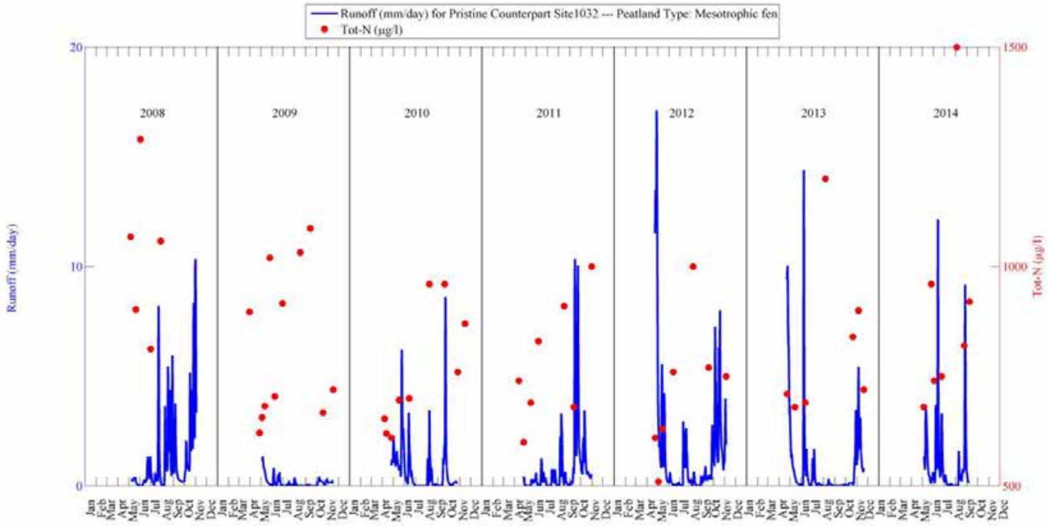

Runoff (mm/day) for Pristine Counterpart Site116 --- Peatland Type: Mesotrophic fen
NH4-N (µg/l)
Date of Restoration (01.09.2011)
Runoff (mm/day)
NH4-N (µg/l)
2008
2009
2010
2011
2012
2013
2014

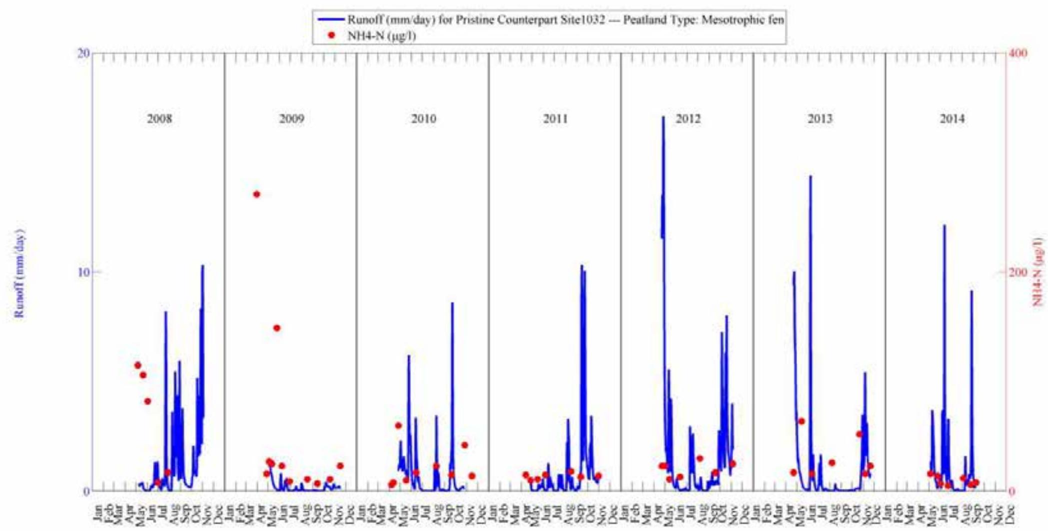

Runoff (mm/day) for Pristine Counterpart Site116 --- Peatland Type: Mesotrophic fen
NO23-N (µg/l)
Date of Restoration (01.09.2011)
Runoff (mm/day)
NO23-N (µg/l)
2008
2009
2010
2011
2012
2013
2014

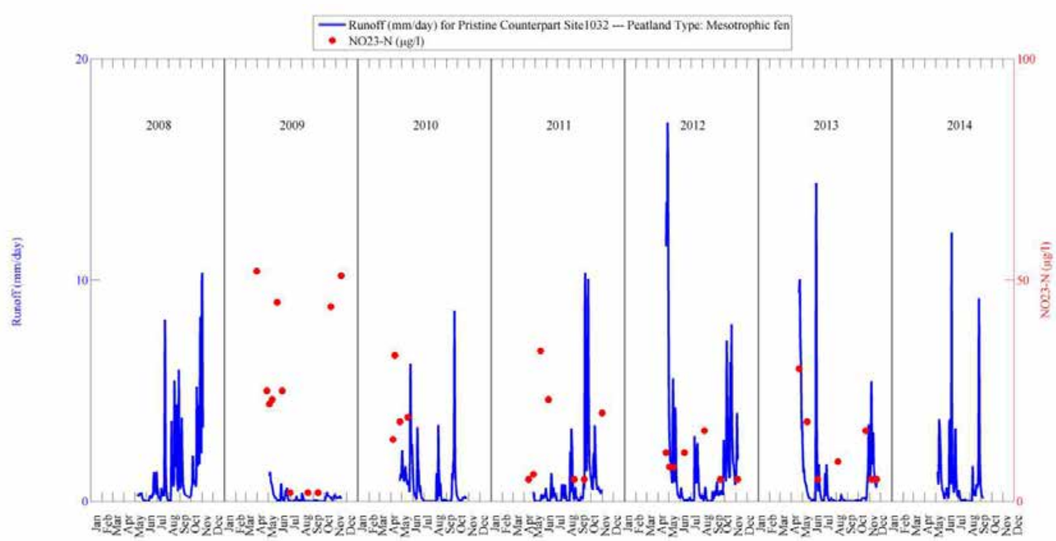

Runoff (mm/day) for Restored Site1031 --- Peatland Type: Mesotrophic fen
Tot-N (µg/l)
Date of Restoration (28.11.2011)
Runoff (mm/day)
Tot-N (µg/l)
2008
2009
2010
2011
2012
2013
2014


Runoff (mm/day) for Restored Site1031 --- Peatland Type: Mesotrophic fen
NH4-N (µg/l)
Date of Restoration (28.11.2011)
Runoff (mm/day)
NH4-N (µg/l)
2008
2009
2010
2011
2012
2013
2014

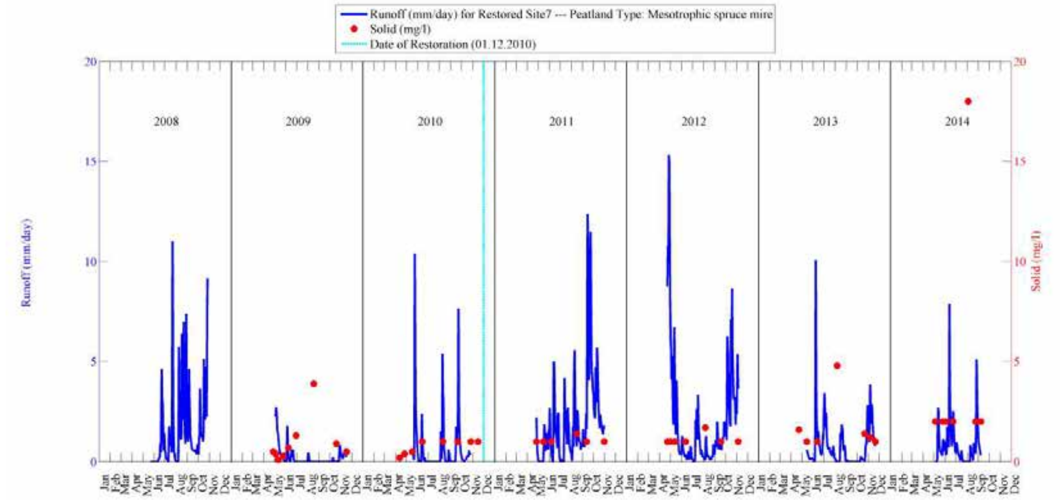

Runoff (mm/day) for Restored Site1031 --- Peatland Type: Mesotrophic fen
NO23-N (µg/l)
Date of Restoration (28.11.2011)
Runoff (mm/day)
NO23-N (µg/l)
2008
2009
2010
2011
2012
2013
2014

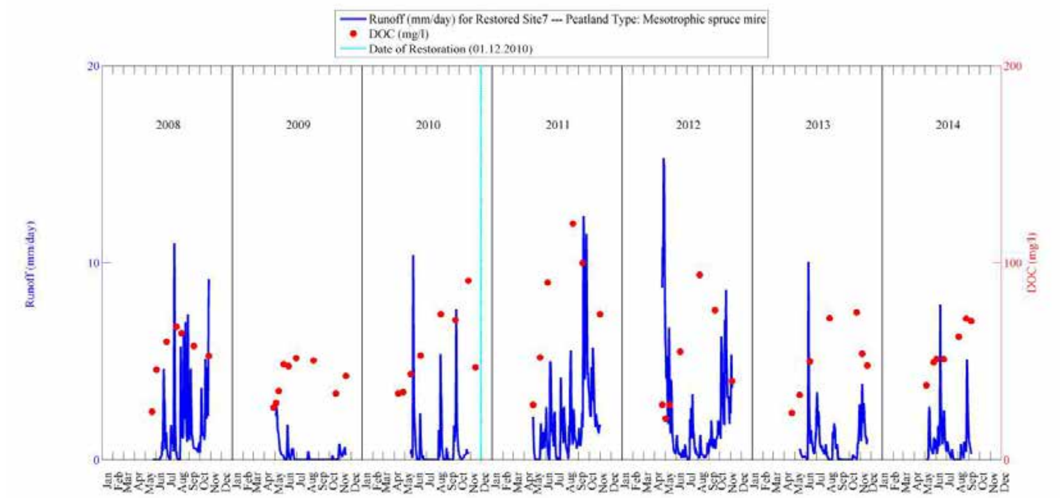

Runoff (mm/day) for Pristine Counterpart Site1032 --- Peatland Type: Mesotrophic fen
Tot-N (µg/l)
Runoff (mm/day)
Tot-N (µg/l)
2008
2009
2010
2011
2012
2013
2014

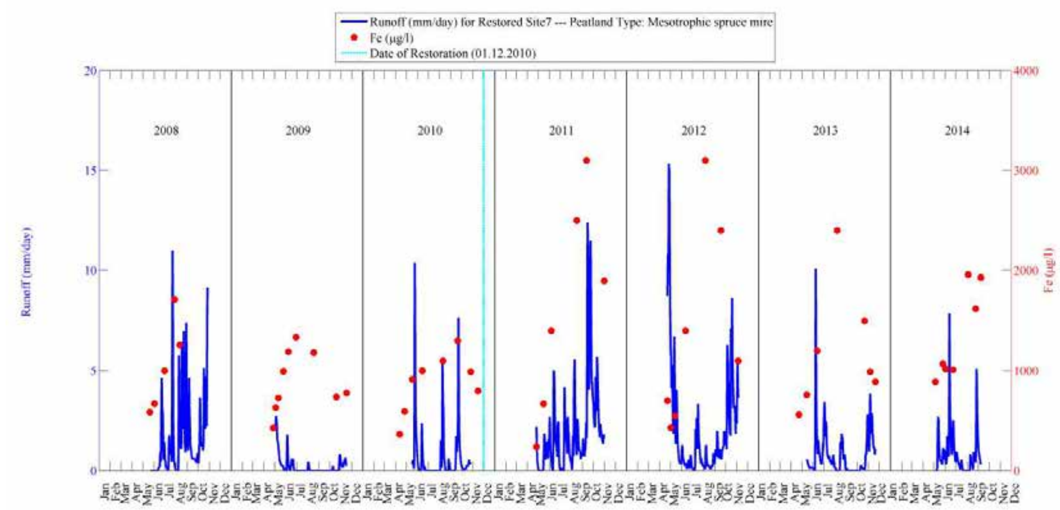

Runoff (mm/day) for Pristine Counterpart Site1032 --- Peatland Type: Mesotrophic fen
NH4-N (µg/l)
Runoff (mm/day)
NH4-N (µg/l)
2008
2009
2010
2011
2012
2013
2014

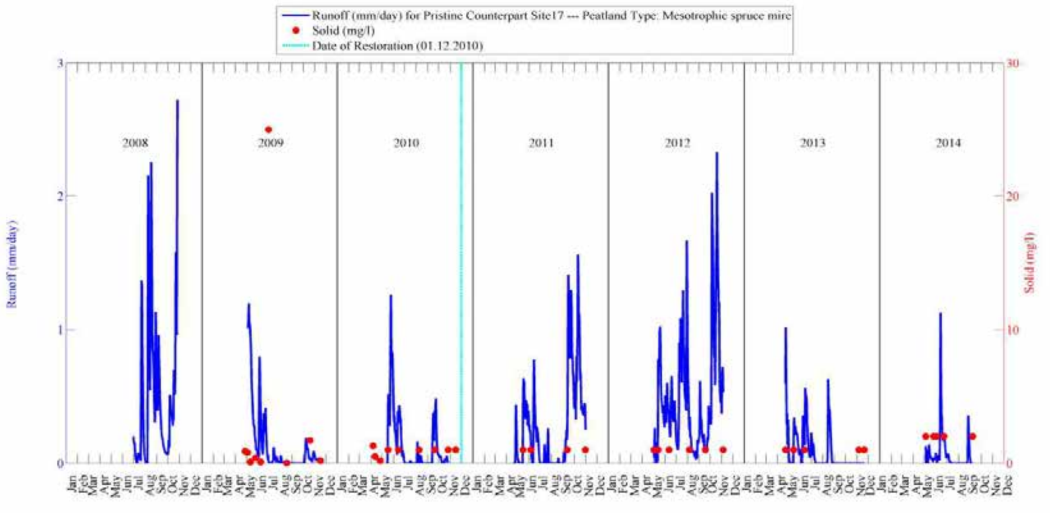

Runoff (mm/day) for Pristine Counterpart Site1032 --- Peatland Type: Mesotrophic fen
NO23-N (µg/l)
Runoff (mm/day)
NO23-N (µg/l)
2008
2009
2010
2011
2012
2013
2014

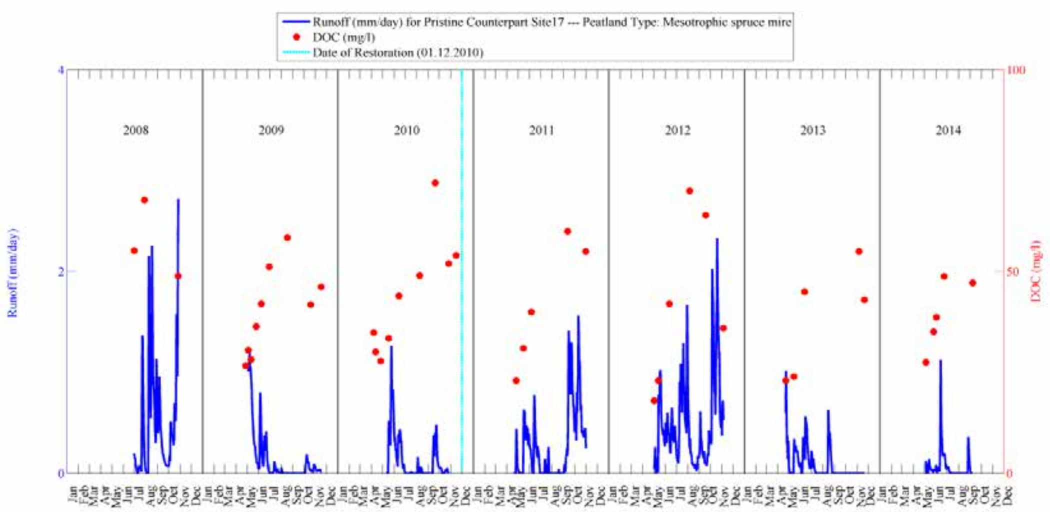
Appendix 5: Runoff (mm d-1) and suspended solids, DOC and Fe concentrations with continuous discharge monitoring (2008-2014).

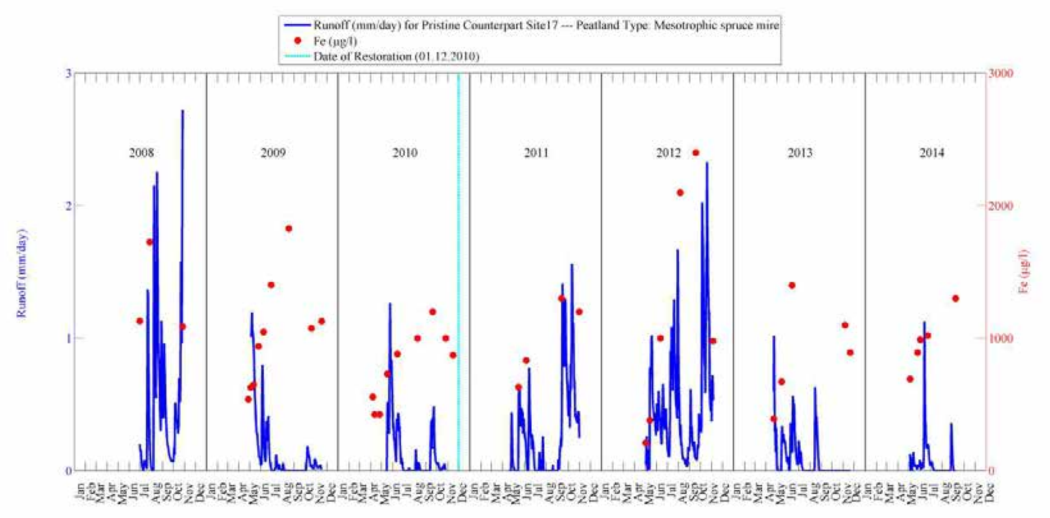


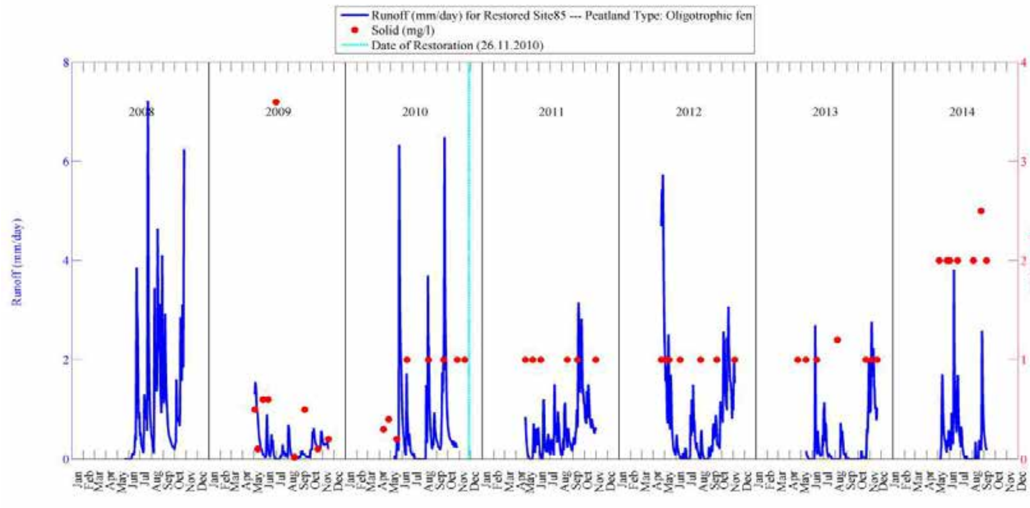


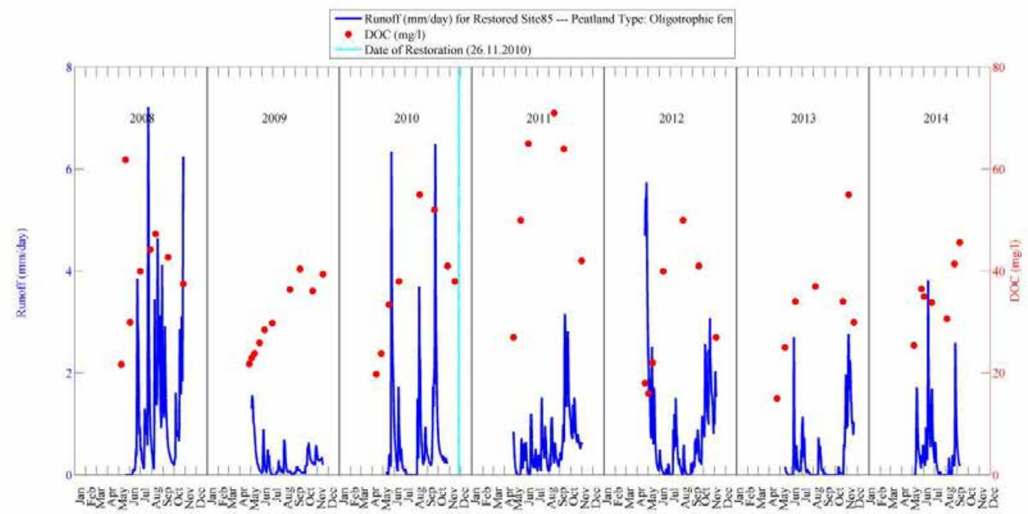


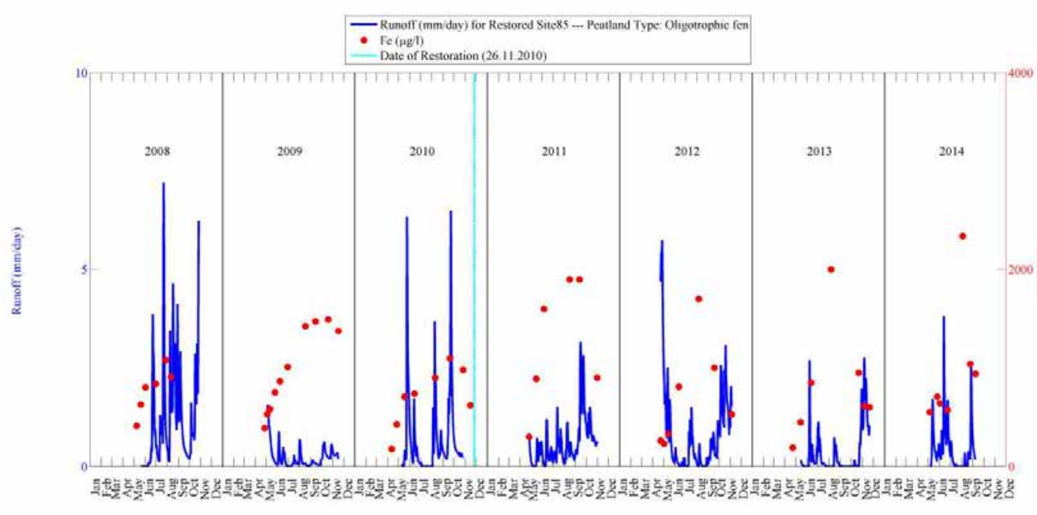

Runoff (mm/day) for Pristine Counterpart Site17 --- Peatland Type: Mesotrophic spruce mire
Solid (mg/l)
Date of Restoration (01.12.2010)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
Solid (mg/l)

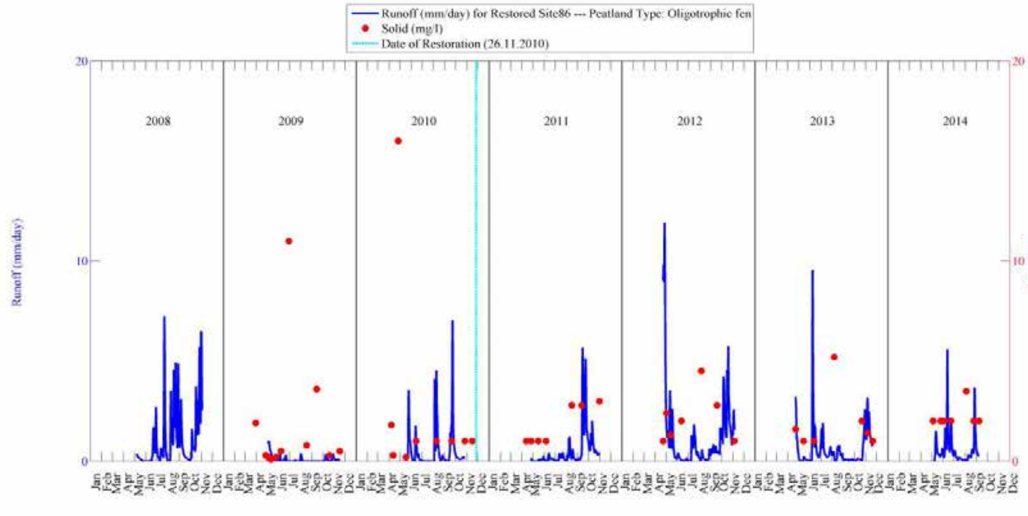

Runoff (mm/day) for Pristine Counterpart Site17 --- Peatland Type: Mesotrophic spruce mire
DOC (mg/l)
Date of Restoration (01.12.2010)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
DOC (mg/l)


Runoff (mm/day) for Pristine Counterpart Site17 --- Peatland Type: Mesotrophic spruce mire
Fe (µg/l)
Date of Restoration (01.12.2010)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
Fe (µg/l)

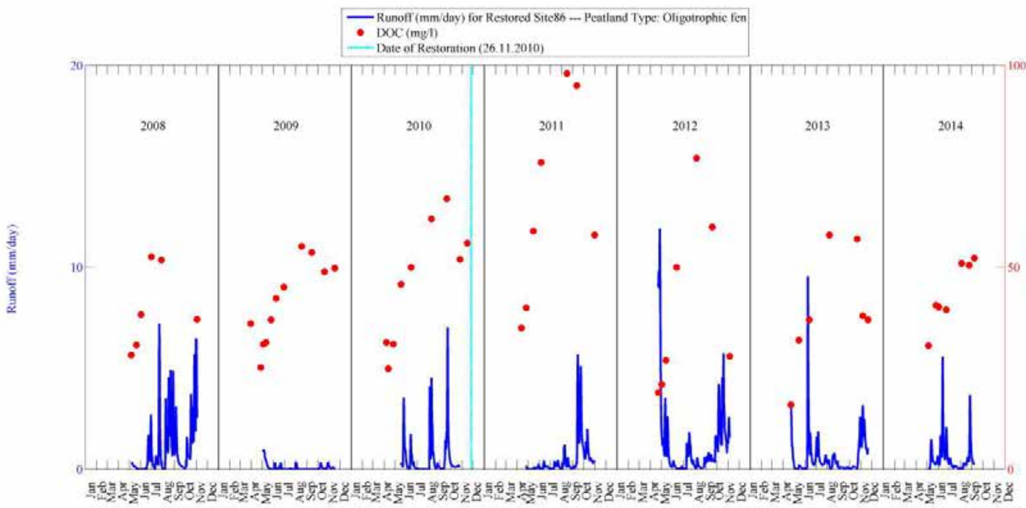

Runoff (mm/day) for Restored Site85 --- Peatland Type: Oligotrophic fen
Solid (mg/l)
Date of Restoration (26.11.2010)
Runoff (mm/day)
Solid (mg/l)
2008
2009
2010
2011
2012
2013
2014


Runoff (mm/day) for Restored Site85 --- Peatland Type: Oligotrophic fen
DOC (mg/l)
Date of Restoration (26.11.2010)
Runoff (mm/day)
DOC (mg/l)
2008
2009
2010
2011
2012
2013
2014

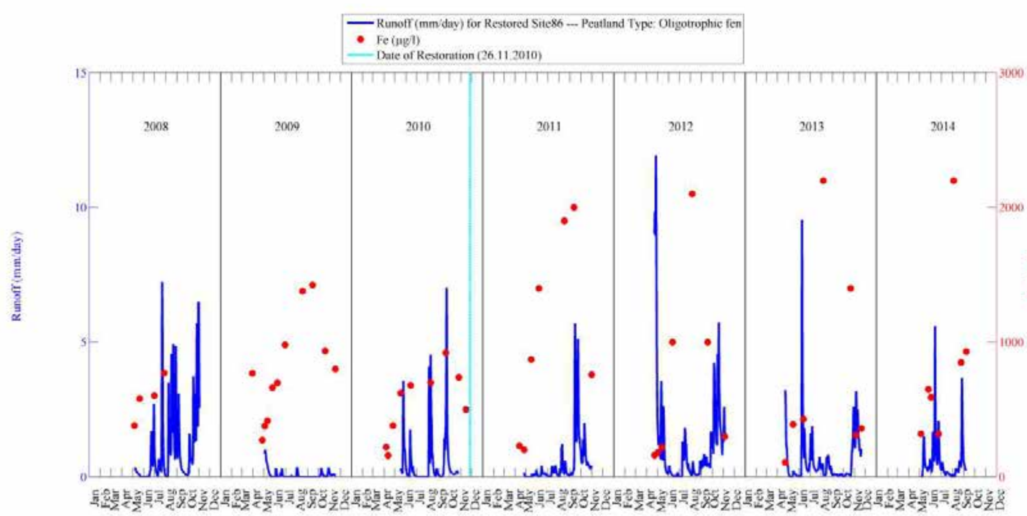

Runoff (mm/day) for Restored Site85 --- Peatland Type: Oligotrophic fen
Fe (µg/l)
Date of Restoration (26.11.2010)
Runoff (mm/day)
Fe (µg/l)
2008
2009
2010
2011
2012
2013
2014



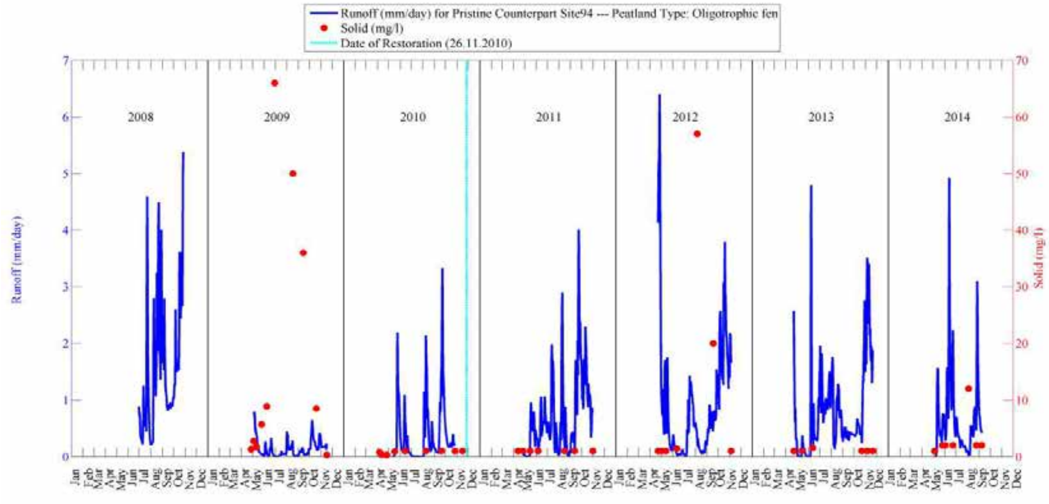
Runoff (mm/day) for Restored Site86 --- Peatland Type: Oligotrophic fen
Solid (mg/l)
Date of Restoration (26.11.2010)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
Solid (mg/l)



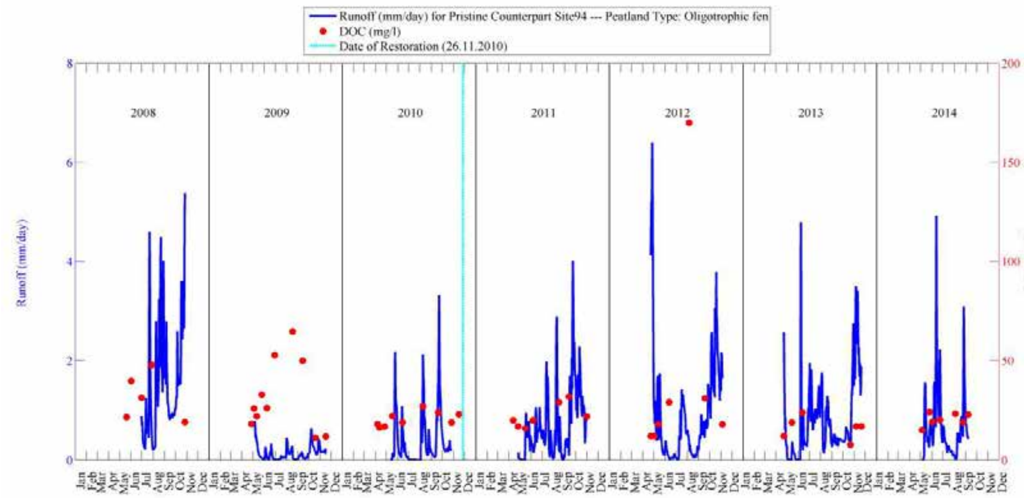
Runoff (mm/day) for Restored Site86 --- Peatland Type: Oligotrophic fen
DOC (mg/l)
Date of Restoration (26.11.2010)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
DOC (mg/l)



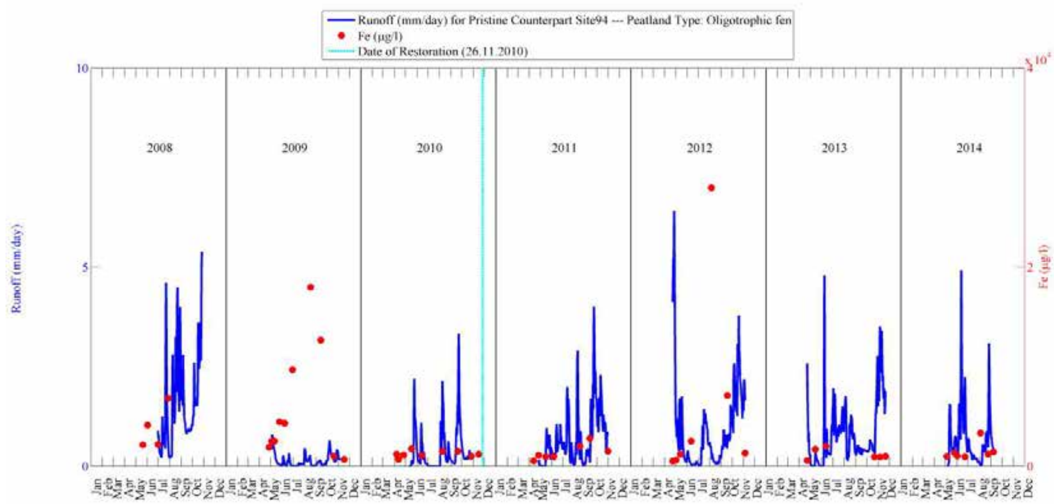
Runoff (mm/day) for Restored Site86 --- Peatland Type: Oligotrophic fen
Fe (µg/l)
Date of Restoration (26.11.2010)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
Fe (µg/l)



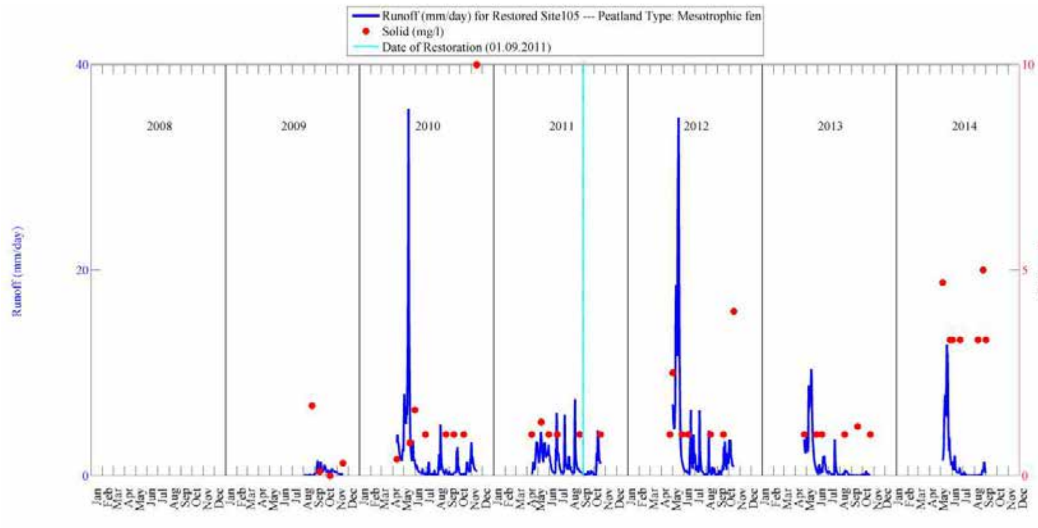
Runoff (mm/day) for Pristine Counterpart Site94 --- Peatland Type: Oligotrophic fen
Solid (mg/l)
Date of Restoration (26.11.2010)
Runoff (mm/day)
Solid (mg/l)
2008
2009
2010
2011
2012
2013
2014

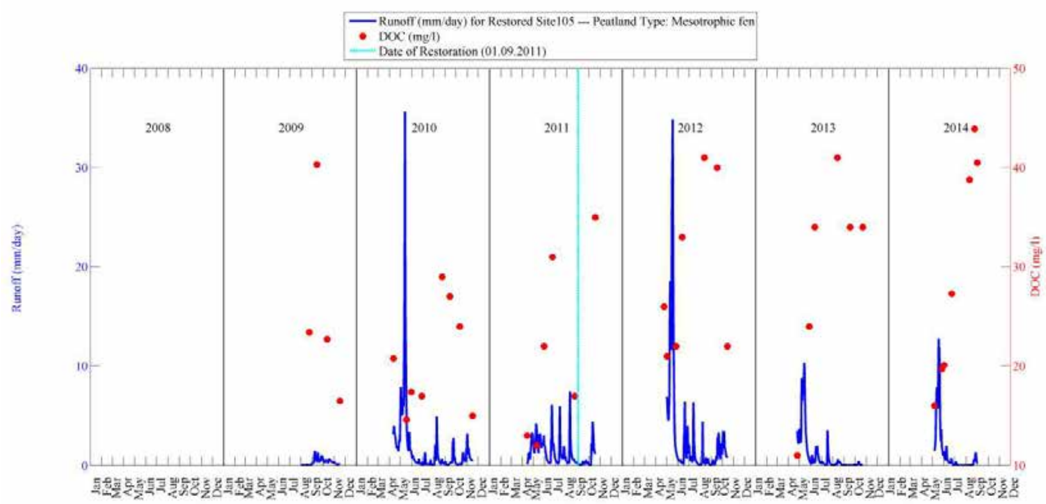


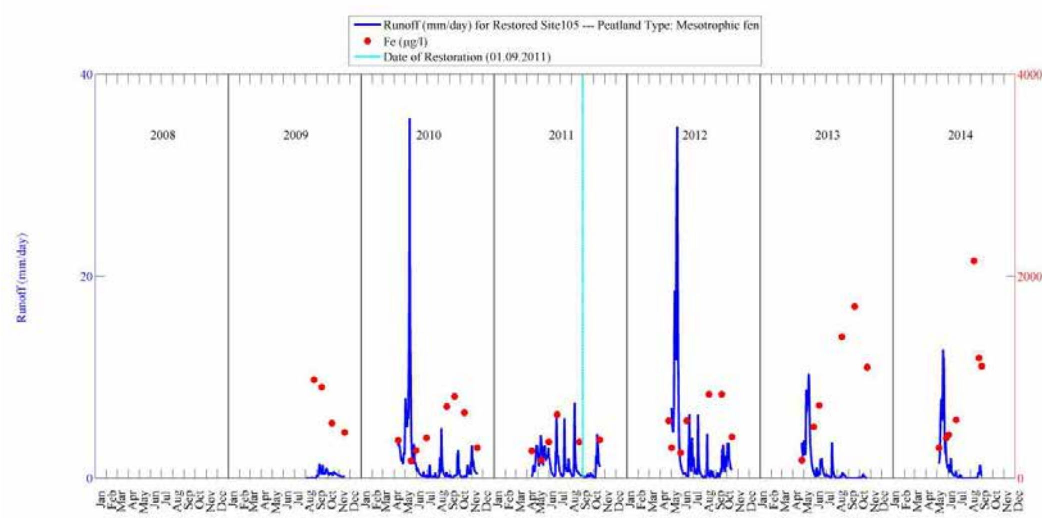
Runoff (mm/day) for Pristine Counterpart Site94 --- Peatland Type: Oligotrophic fen
DOC (mg/l)
Date of Restoration (26.11.2010)
Runoff (mm/day)
DOC (mg/l)
2008
2009
2010
2011
2012
2013
2014

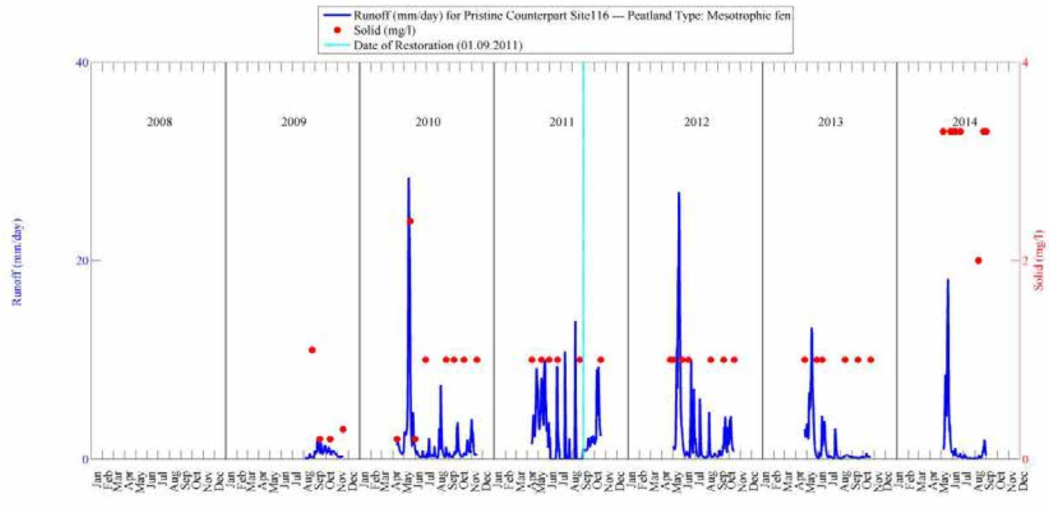


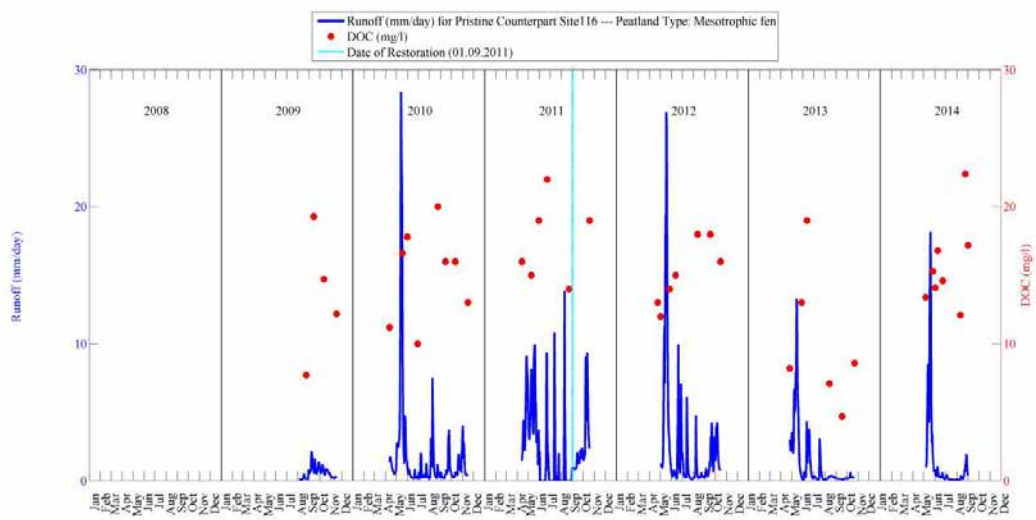
Runoff (mm/day) for Pristine Counterpart Site94 --- Peatland Type: Oligotrophic fen
Fe (µg/l)
Date of Restoration (26.11.2010)
Runoff (mm/day)
Fe (µg/l)
2008
2009
2010
2011
2012
2013
2014

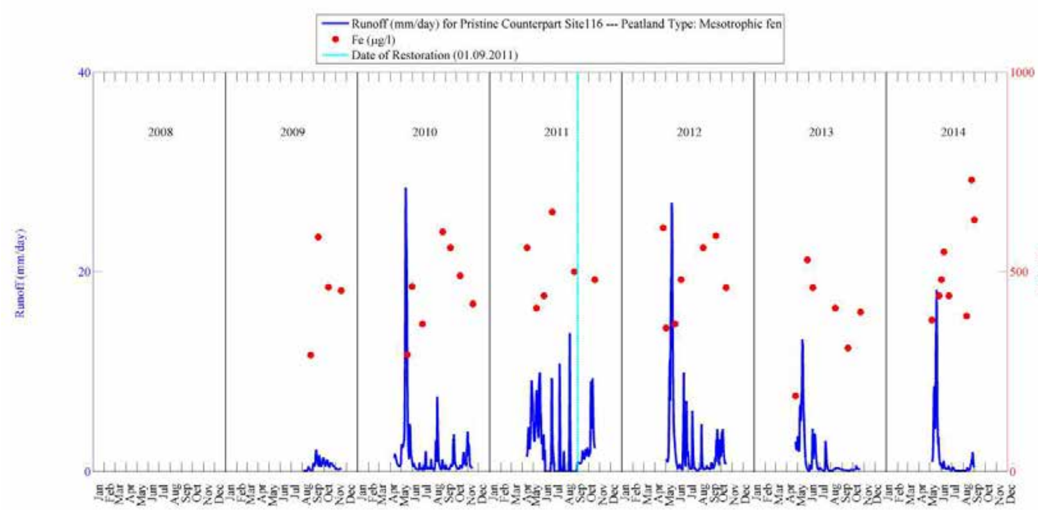

Runoff (mm/day) for Restored Site105 --- Peatland Type: Mesotrophic fen
Solid (mg/l)
Date of Restoration (01.09.2011)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
Solid (mg/l)

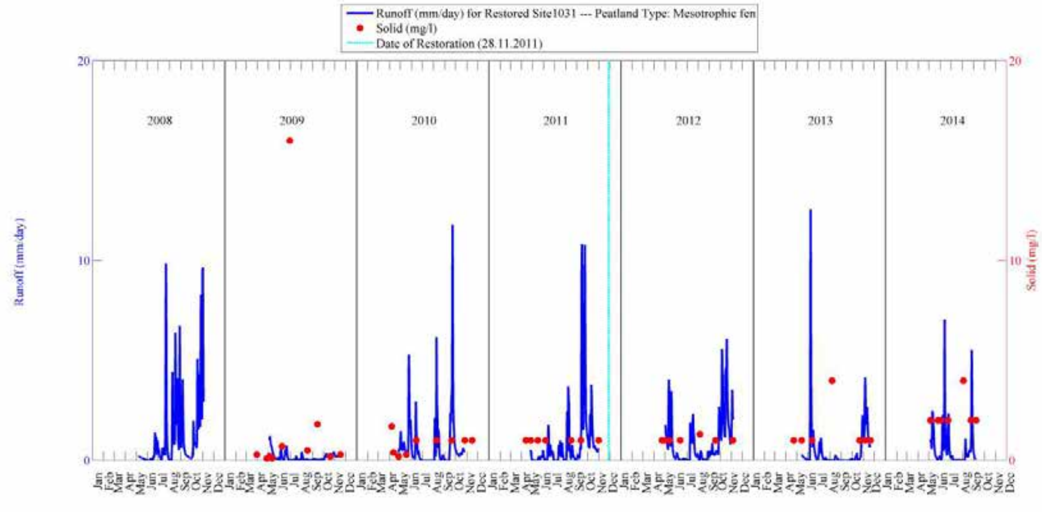

Runoff (mm/day) for Restored Site105 --- Peatland Type: Mesotrophic fen
DOC (mg/l)
Date of Restoration (01.09.2011)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
DOC (mg/l)

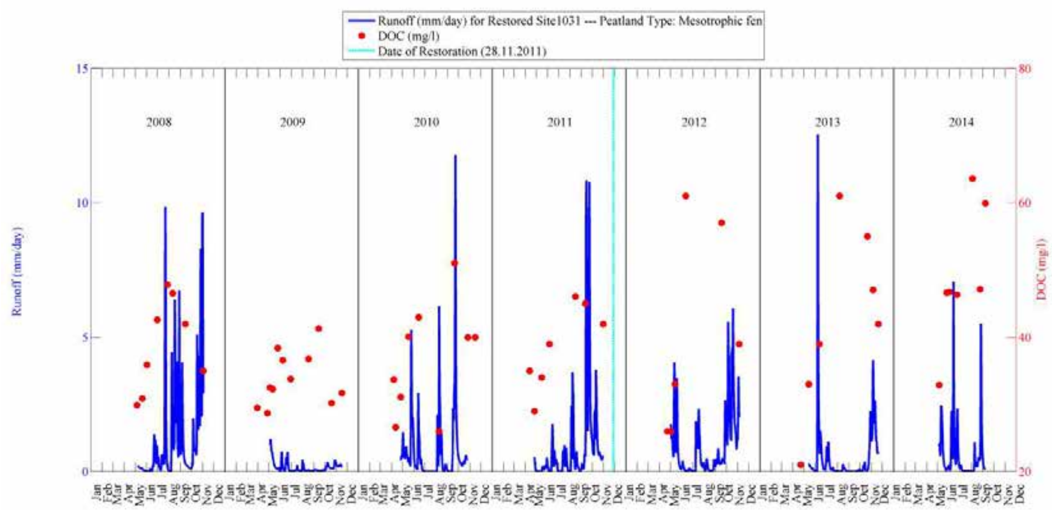

Runoff (mm/day) for Restored Site105 --- Peatland Type: Mesotrophic fen
Fe (µg/l)
Date of Restoration (01.09.2011)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
Fe (µg/l)

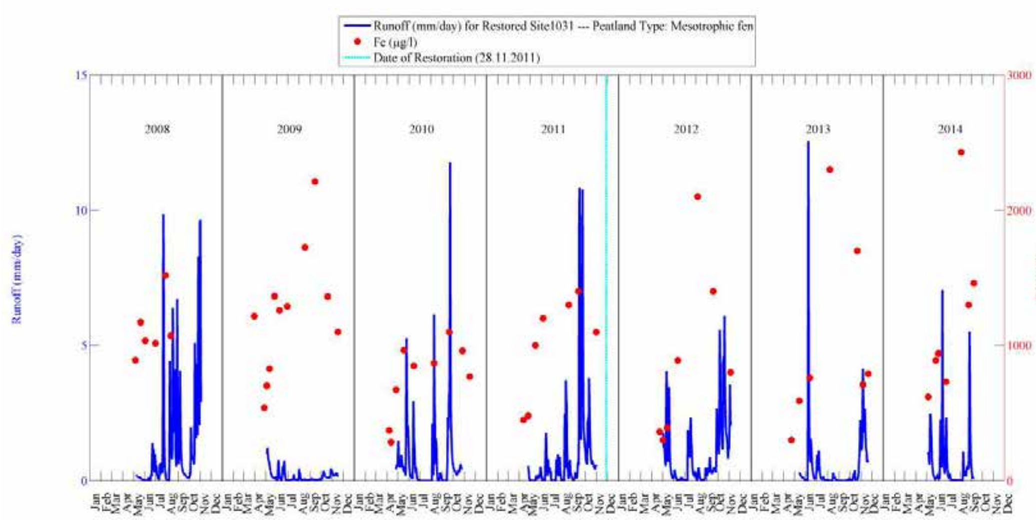

Runoff (mm/day) for Pristine Counterpart Site116 --- Peatland Type: Mesotrophic fen
Solid (mg/l)
Date of Restoration (01.09.2011)
Runoff (mm/day)
Solid (mg/l)
2008
2009
2010
2011
2012
2013
2014

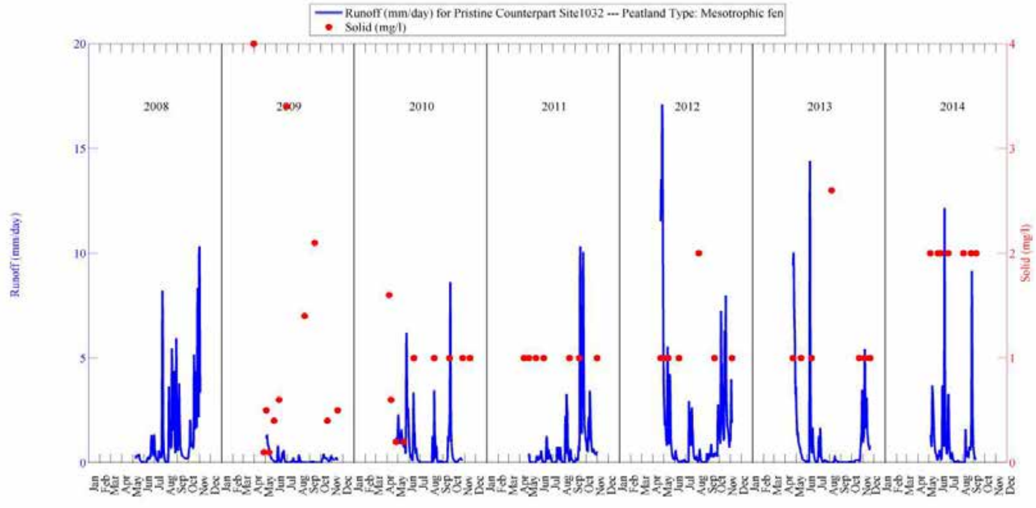

Runoff (mm/day) for Pristine Counterpart Site116 --- Peatland Type: Mesotrophic fen
DOC (mg/l)
Date of Restoration (01.09.2011)
Runoff (mm/day)
DOC (mg/l)
2008
2009
2010
2011
2012
2013
2014

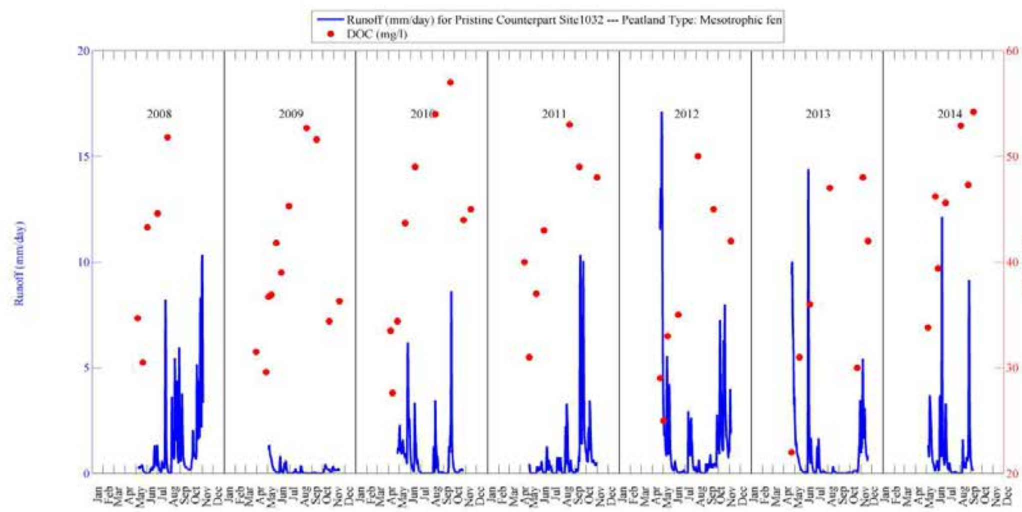

Runoff (mm/day) for Pristine Counterpart Site116 --- Peatland Type: Mesotrophic fen
Fe (µg/l)
Date of Restoration (01.09.2011)
Runoff (mm/day)
Fe (µg/l)
2008
2009
2010
2011
2012
2013
2014

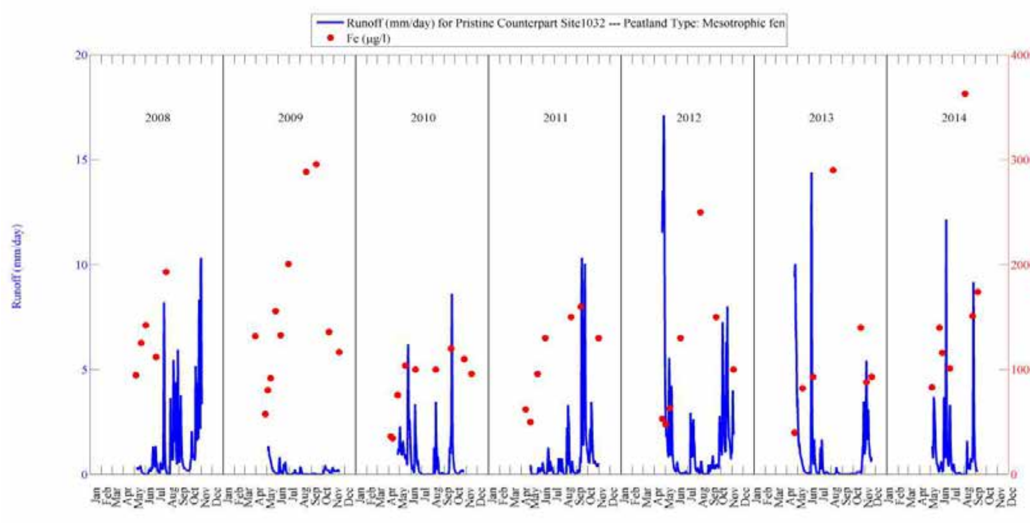

Runoff (mm/day) for Restored Site1031 --- Peatland Type: Mesotrophic fen
Solid (mg/l)
Date of Restoration (28.11.2011)
Runoff (mm/day)
Solid (mg/l)
0
10
20
2008
2009
2010
2011
2012
2013
2014


Runoff (mm/day) for Restored Site1031 --- Peatland Type: Mesotrophic fen
DOC (mg/l)
Date of Restoration (28.11.2011)
Runoff (mm/day)
DOC (mg/l)
0
5
10
15
20
40
60
80
2008
2009
2010
2011
2012
2013
2014

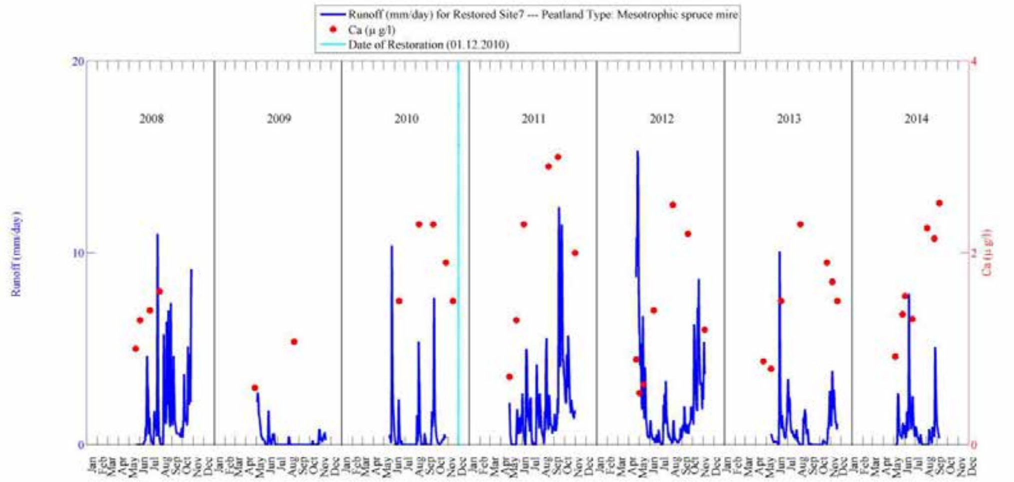

Runoff (mm/day) for Restored Site1031 --- Peatland Type: Mesotrophic fen
Fe (µg/l)
Date of Restoration (28.11.2011)
Runoff (mm/day)
Fe (µg/l)
0
5
10
15
1000
2000
3000
2008
2009
2010
2011
2012
2013
2014

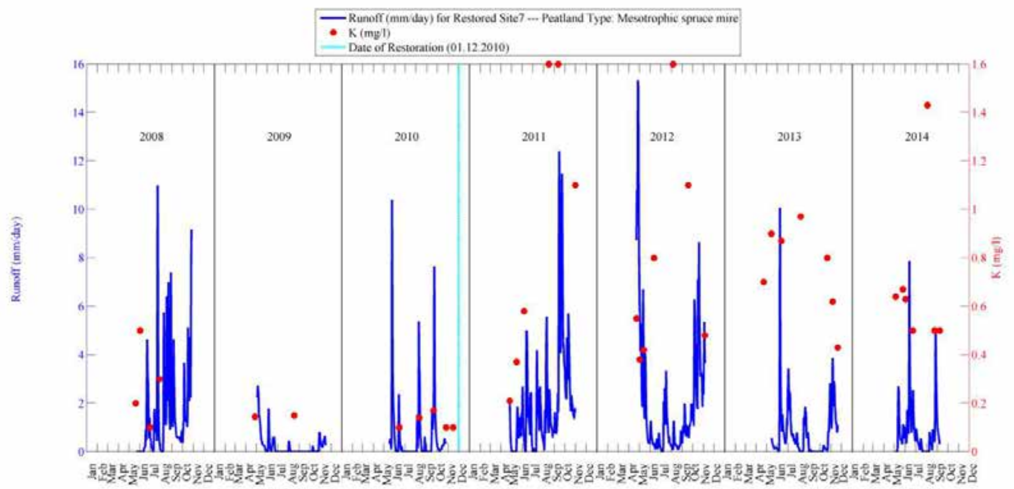

Runoff (mm/day) for Pristine Counterpart Site1032 --- Peatland Type: Mesotrophic fen
Solid (mg/l)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
Solid (mg/l)

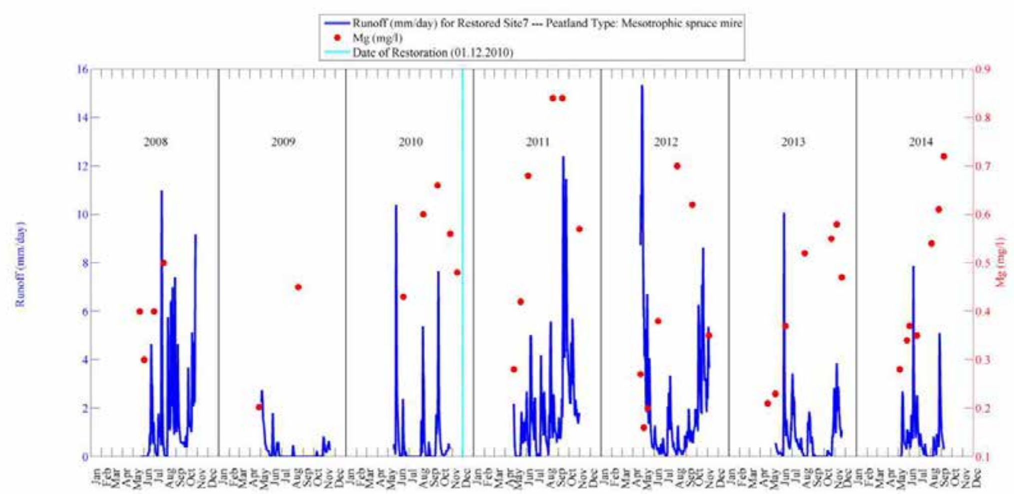

Runoff (mm/day) for Pristine Counterpart Site1032 --- Peatland Type: Mesotrophic fen
DOC (mg/l)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
DOC (mg/l)

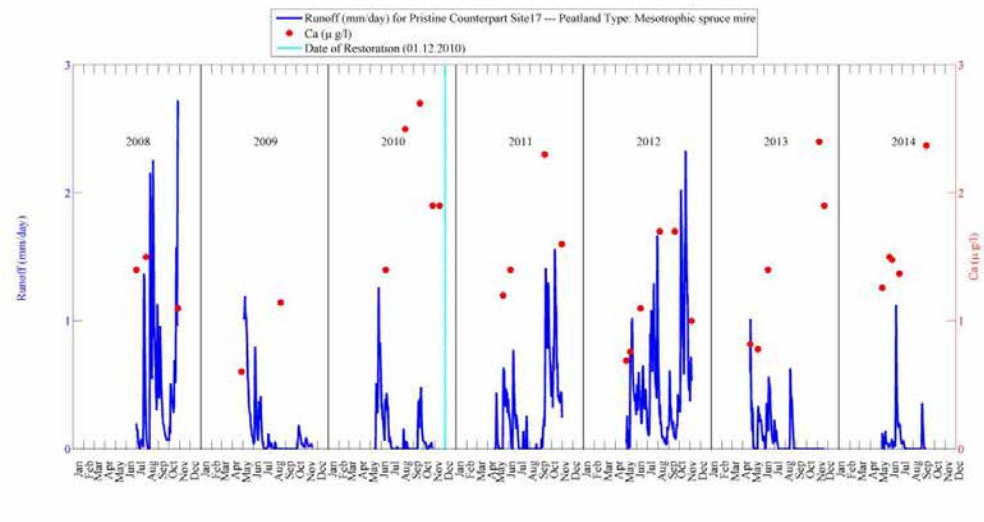

Runoff (mm/day) for Pristine Counterpart Site1032 --- Peatland Type: Mesotrophic fen
Fe (µg/l)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
Fe (µg/l)

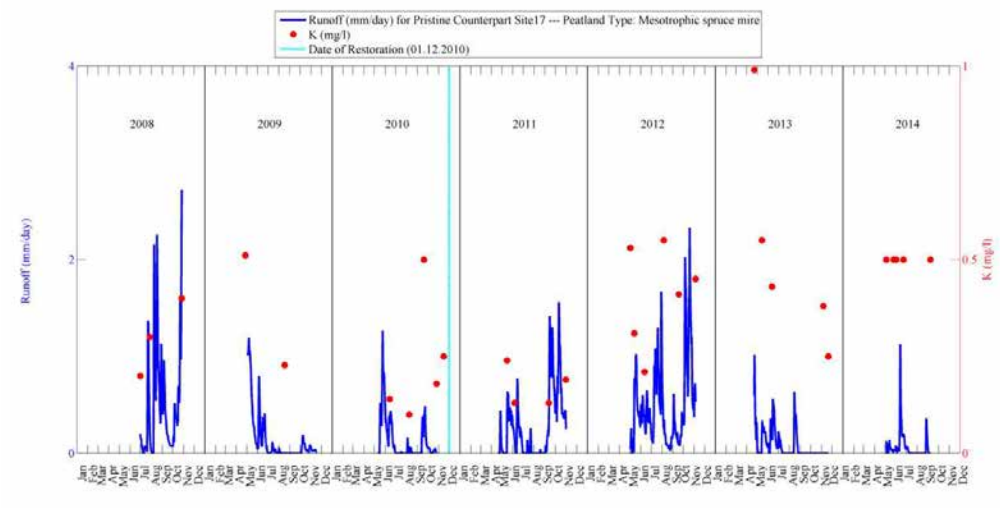
Appendix 6: Runoff (mm d^{-1}), Ca, K and Mg concentrations with continuous discharge monitoring (2008-2014).

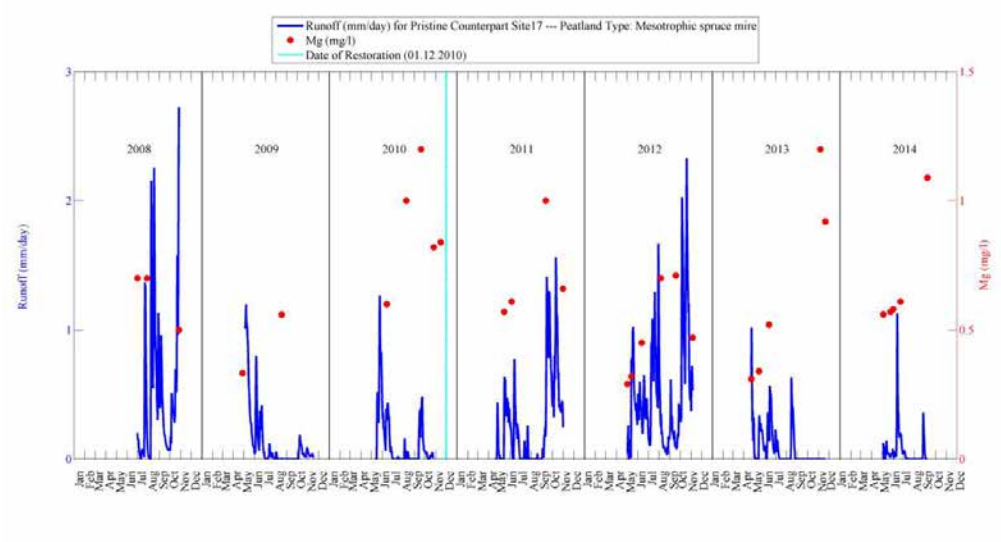


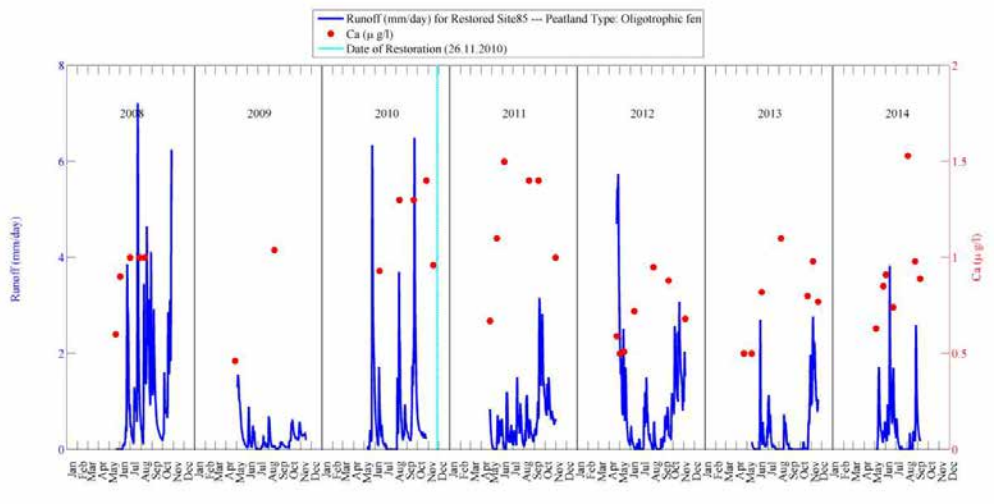


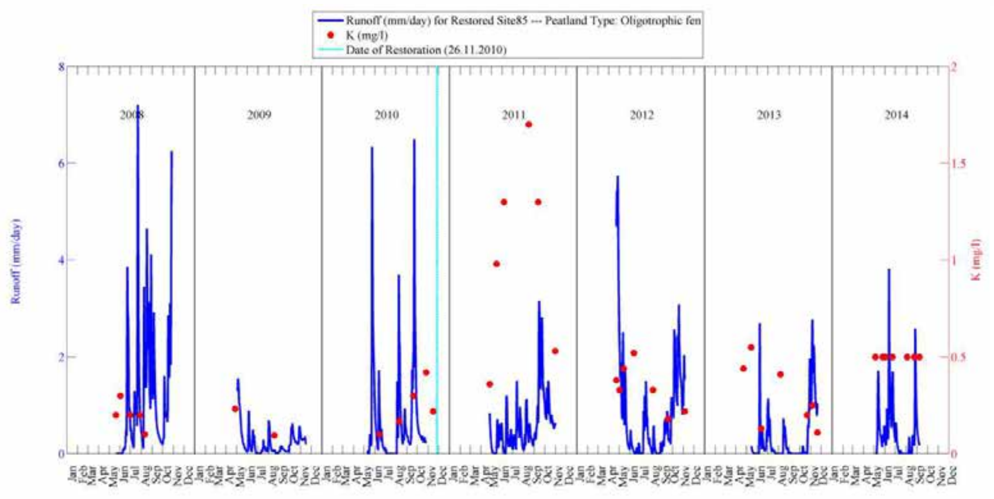


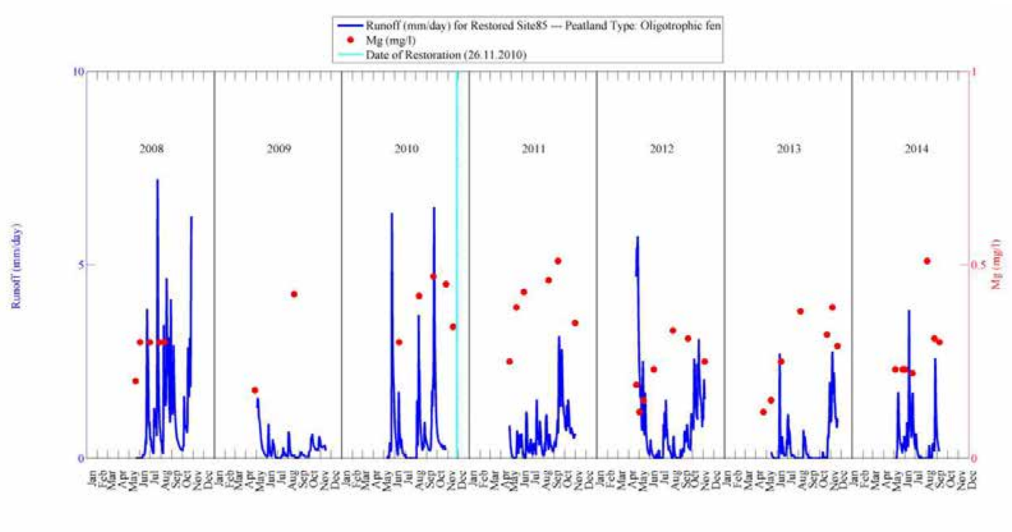

Runoff (mm/day) for Pristine Counterpart Site17 --- Peatland Type: Mesotrophic spruce mire
Ca (μ g/l)
Date of Restoration (01.12.2010)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
Ca (μ g/l)

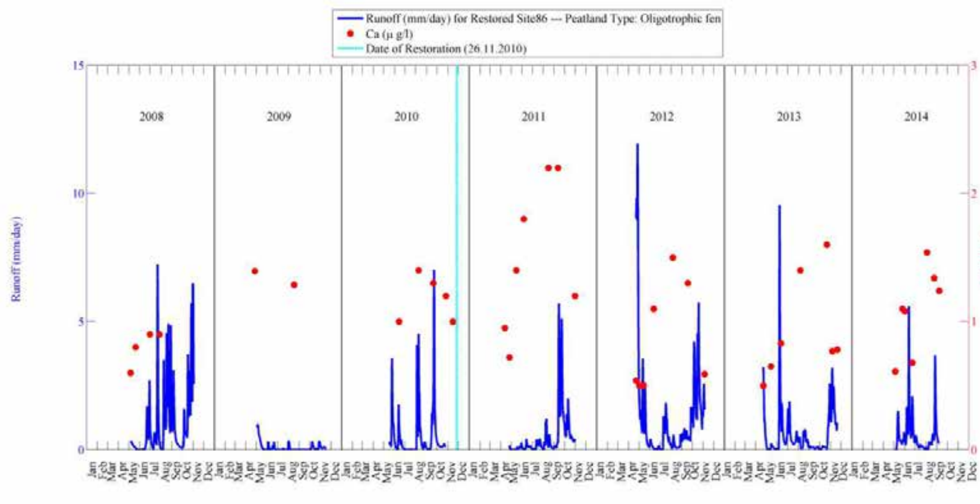

Runoff (mm/day) for Pristine Counterpart Site17 --- Peatland Type: Mesotrophic spruce mire
K (mg/l)
Date of Restoration (01.12.2010)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
K (mg/l)

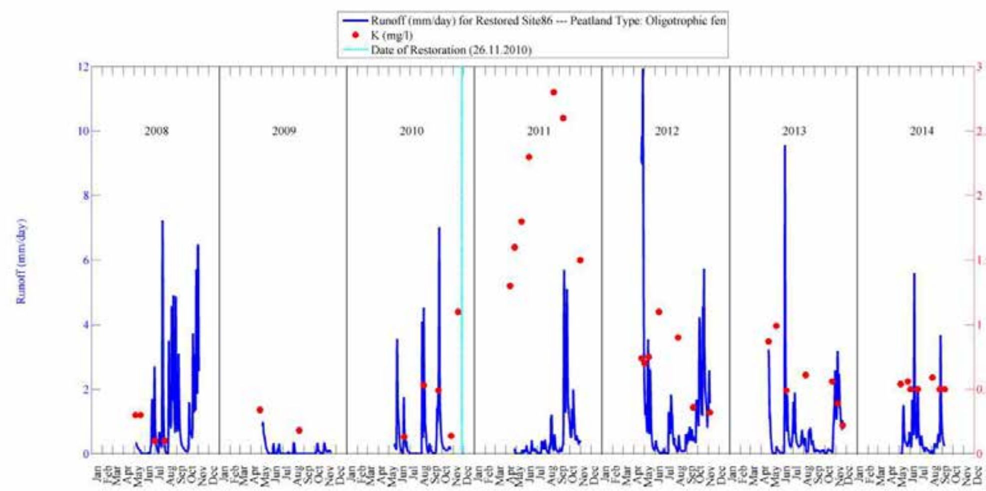

Runoff (mm/day) for Pristine Counterpart Site17 --- Peatland Type: Mesotrophic spruce mire
Mg (mg/l)
Date of Restoration (01.12.2010)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
Mg (mg/l)

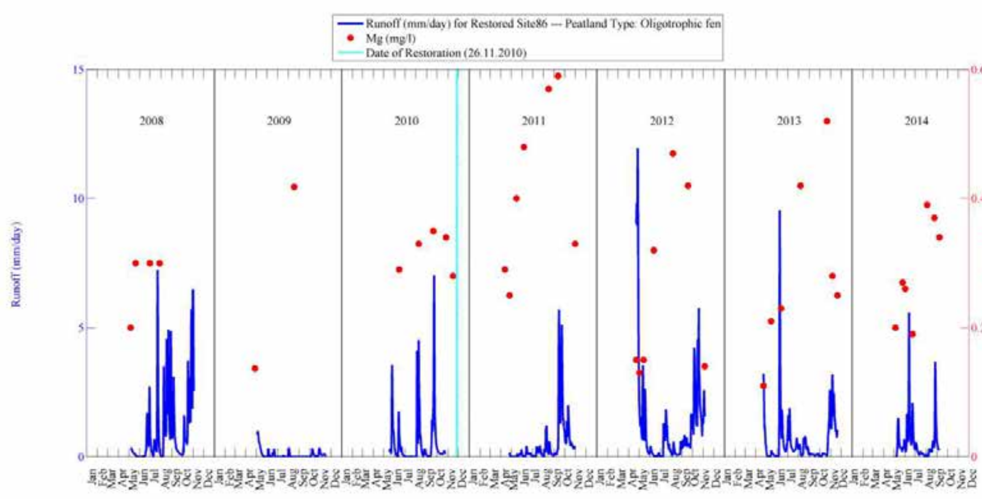

Runoff (mm/day) for Restored Site85 --- Peatland Type: Oligotrophic fen
Ca (µ g/l)
Date of Restoration (26.11.2010)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
Ca (µ g/l)

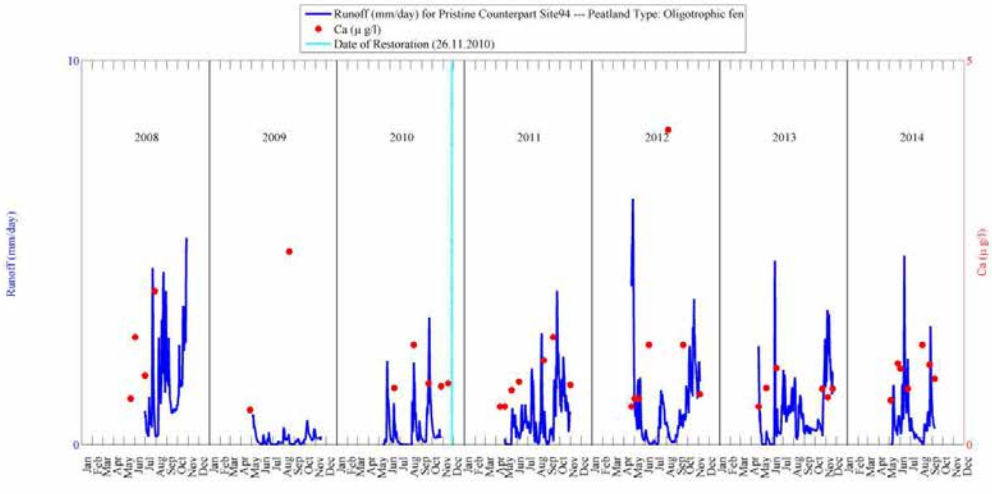

Runoff (mm/day) for Restored Site85 --- Peatland Type: Oligotrophic fen
K (mg/l)
Date of Restoration (26.11.2010)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
K (mg/l)

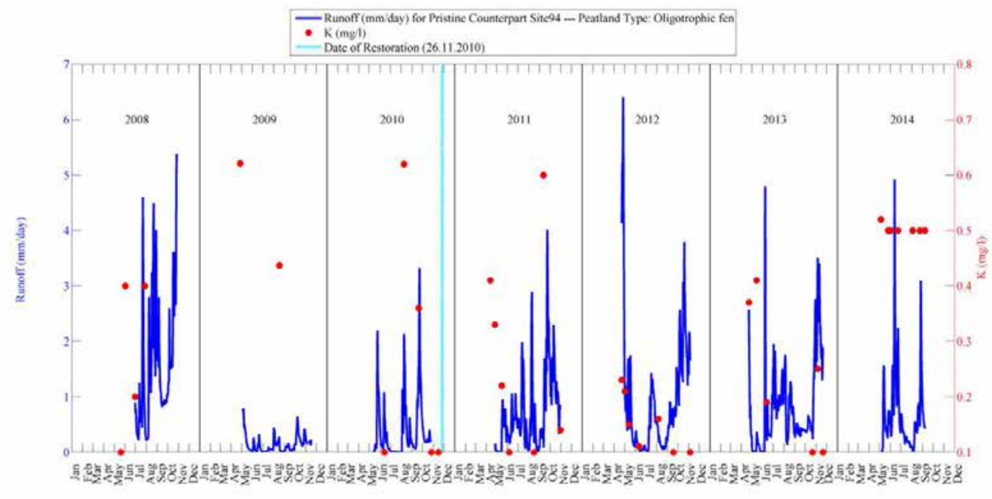

Runoff (mm/day) for Restored Site85 --- Peatland Type: Oligotrophic fen
Mg (mg/l)
Date of Restoration (26.11.2010)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
Mg (mg/l)

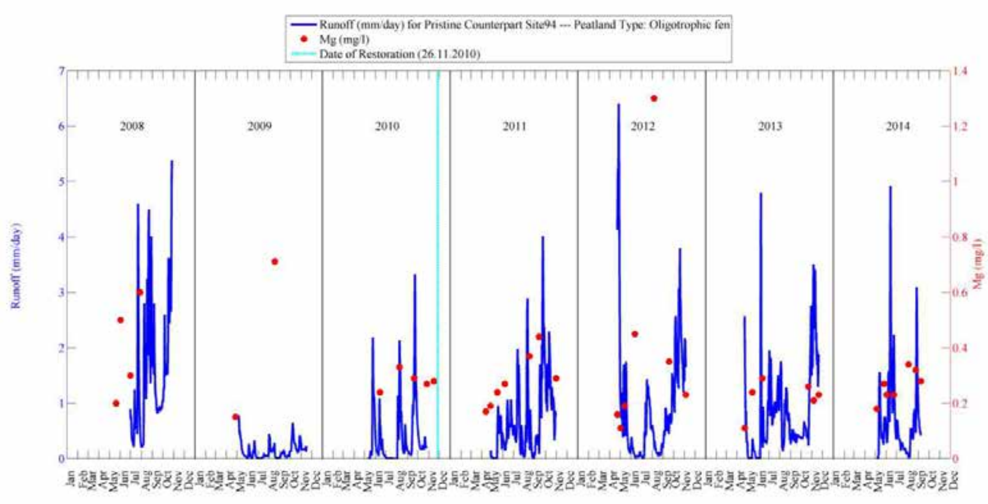

Runoff (mm/day) for Restored Site86 --- Peatland Type: Oligotrophic fen
Ca (µ g/l)
Date of Restoration (26.11.2010)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
Ca (µ g/l)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

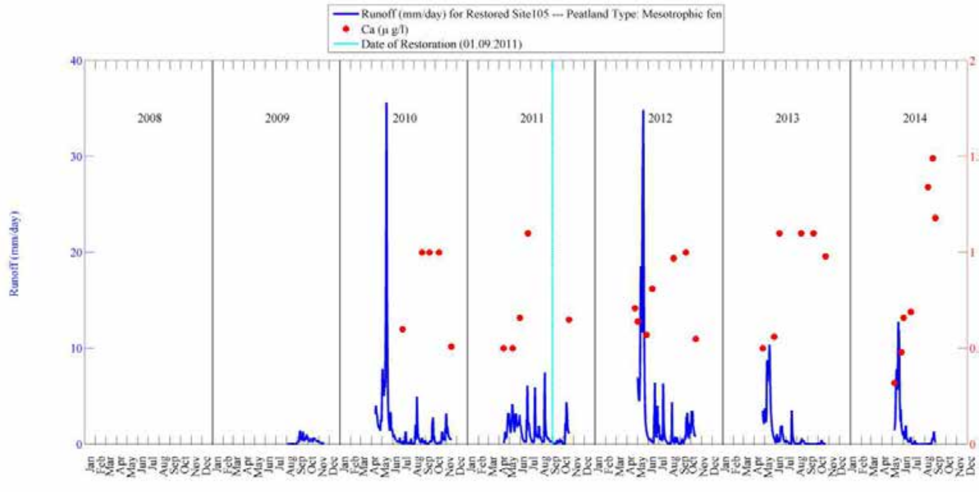

Runoff (mm/day) for Restored Site86 --- Peatland Type: Oligotrophic fen
K (mg/l)
Date of Restoration (26.11.2010)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
K (mg/l)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


Runoff (mm/day) for Restored Site86 --- Peatland Type: Oligotrophic fen
Mg (mg/l)
Date of Restoration (26.11.2010)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
Mg (mg/l)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

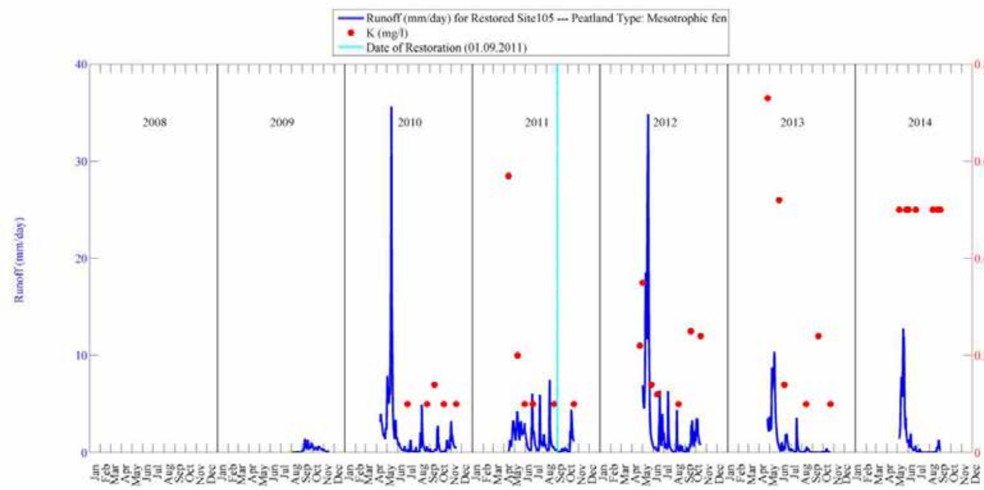

Runoff (mm/day) for Pristine Counterpart Site94 --- Peatland Type: Oligotrophic fen
Ca (µ g/l)
Date of Restoration (26.11.2010)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
Ca (µ g/l)


Runoff (mm/day) for Pristine Counterpart Site94 --- Peatland Type: Oligotrophic fen
K (mg/l)
Date of Restoration (26.11.2010)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
K (mg/l)

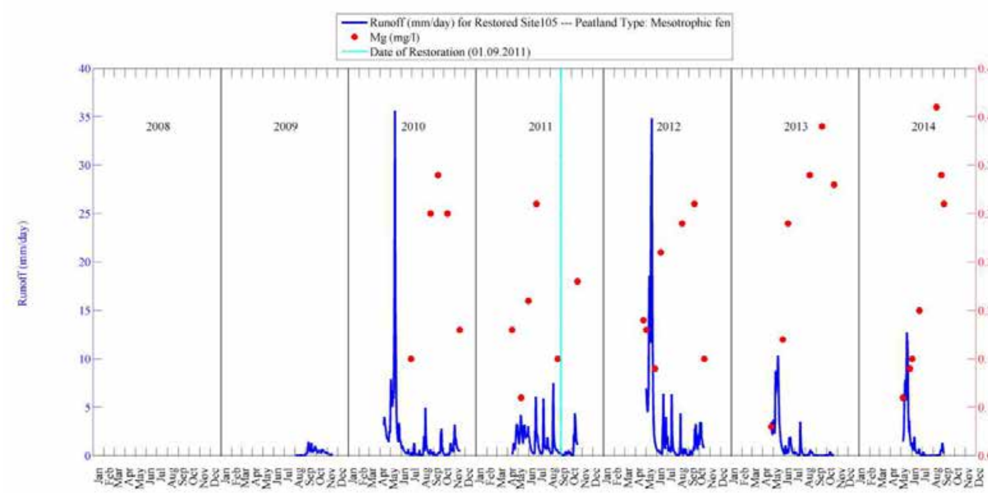

Runoff (mm/day) for Pristine Counterpart Site94 --- Peatland Type: Oligotrophic fen
Mg (mg/l)
Date of Restoration (26.11.2010)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
Mg (mg/l)



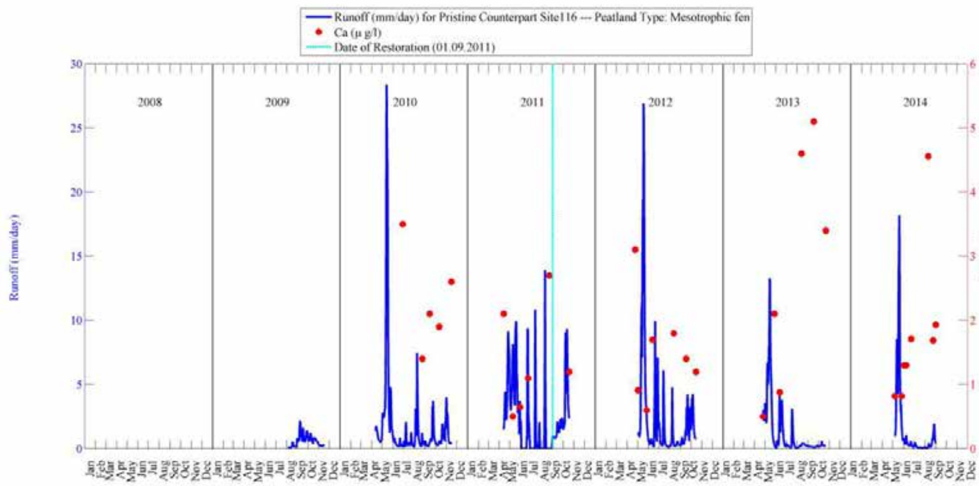
Runoff (mm/day) for Restored Site105 --- Peatland Type: Mesotrophic fen
Ca (μ g/l)
Date of Restoration (01.09.2011)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
Ca (μ g/l)

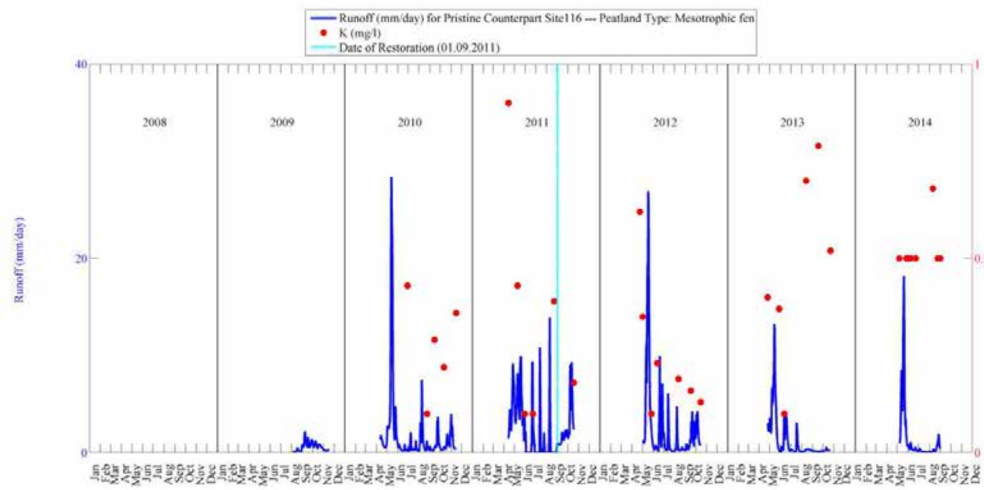


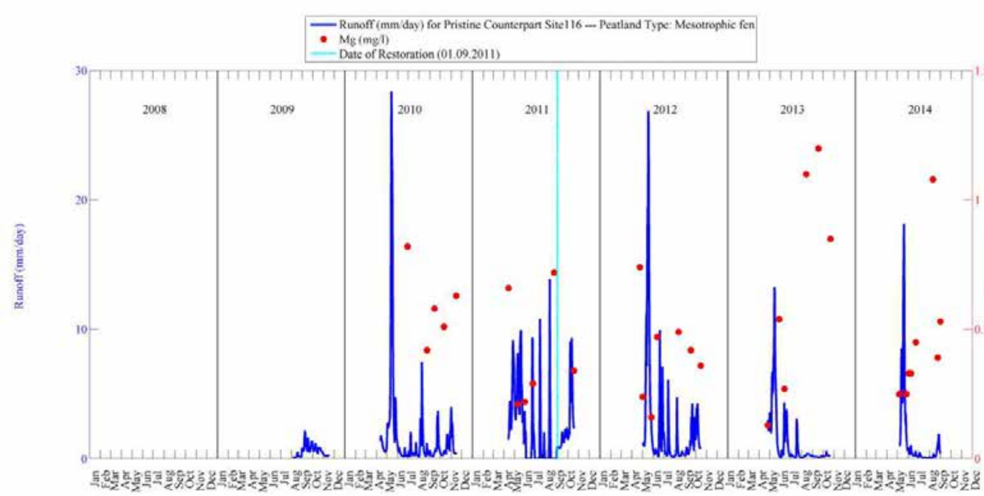
Runoff (mm/day) for Restored Site105 --- Peatland Type: Mesotrophic fen
K (mg/l)
Date of Restoration (01.09.2011)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
K (mg/l)

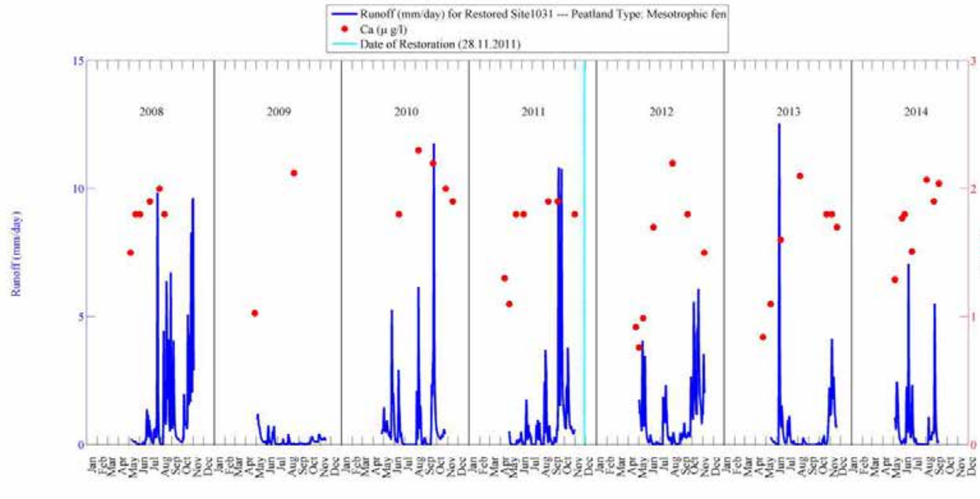


Runoff (mm/day) for Restored Site105 --- Peatland Type: Mesotrophic fen
Mg (mg/l)
Date of Restoration (01.09.2011)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
Mg (mg/l)

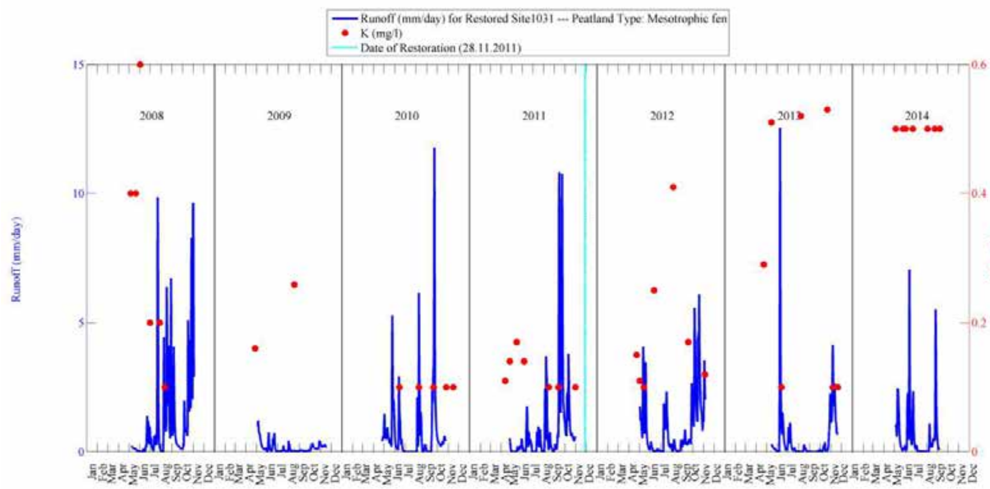

Runoff (mm/day) for Pristine Counterpart Site116 --- Peatland Type: Mesotrophic fen
Ca (µ g/l)
Date of Restoration (01.09.2011)
Runoff (mm/day)
Ca (µ g/l)
2008
2009
2010
2011
2012
2013
2014


Runoff (mm/day) for Pristine Counterpart Site116 --- Peatland Type: Mesotrophic fen
K (mg/l)
Date of Restoration (01.09.2011)
Runoff (mm/day)
K (mg/l)
2008
2009
2010
2011
2012
2013
2014

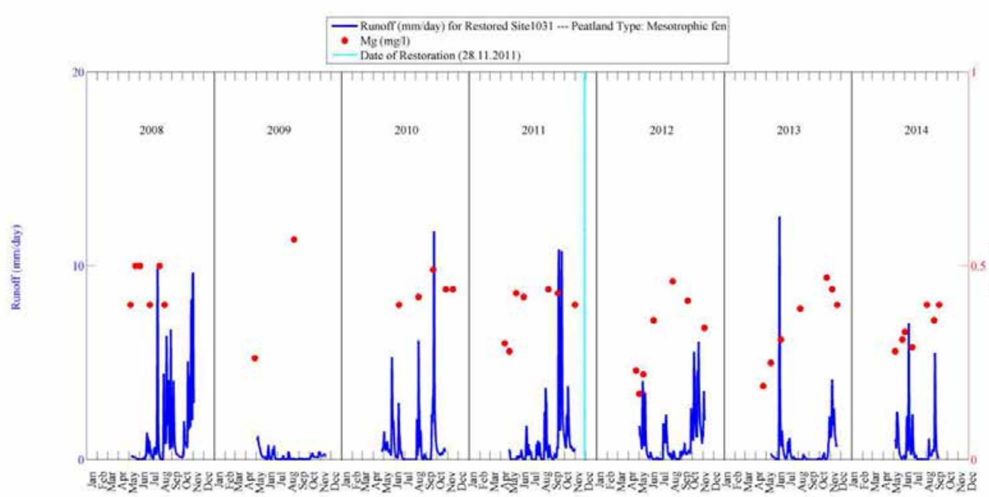

Runoff (mm/day) for Pristine Counterpart Site116 --- Peatland Type: Mesotrophic fen
Mg (mg/l)
Date of Restoration (01.09.2011)
Runoff (mm/day)
Mg (mg/l)
2008
2009
2010
2011
2012
2013
2014



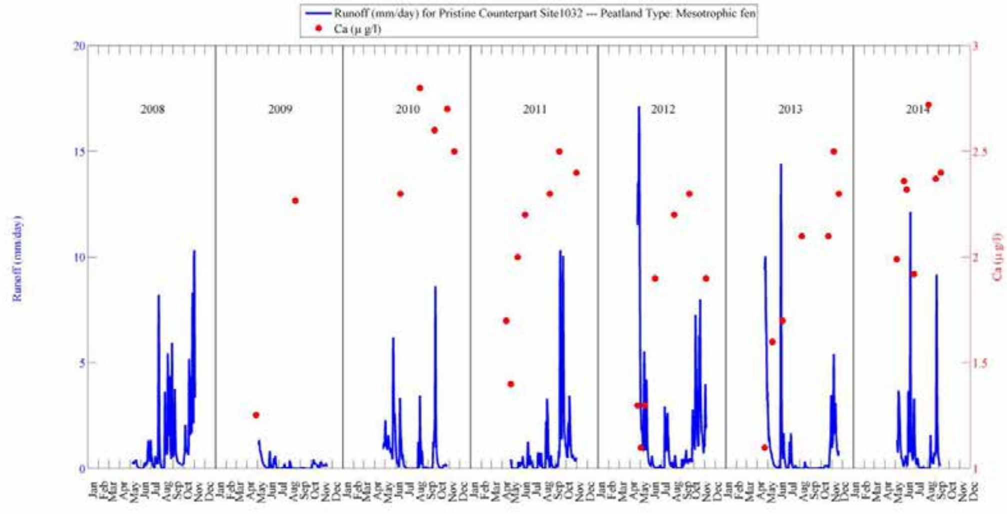
Runoff (mm/day) for Restored Site1031 --- Peatland Type: Mesotrophic fen
Ca (µ g/l)
Date of Restoration (28.11.2011)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
Ca (µ g/l)

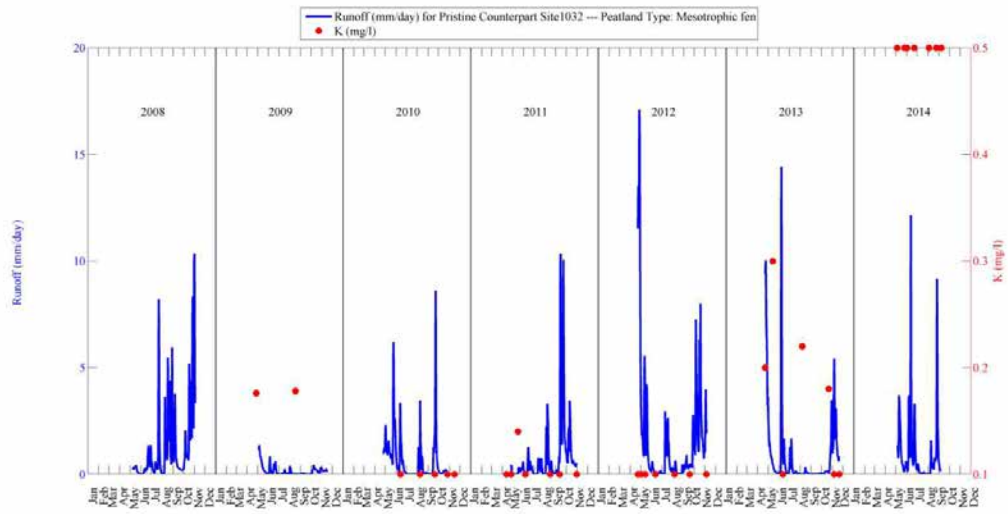


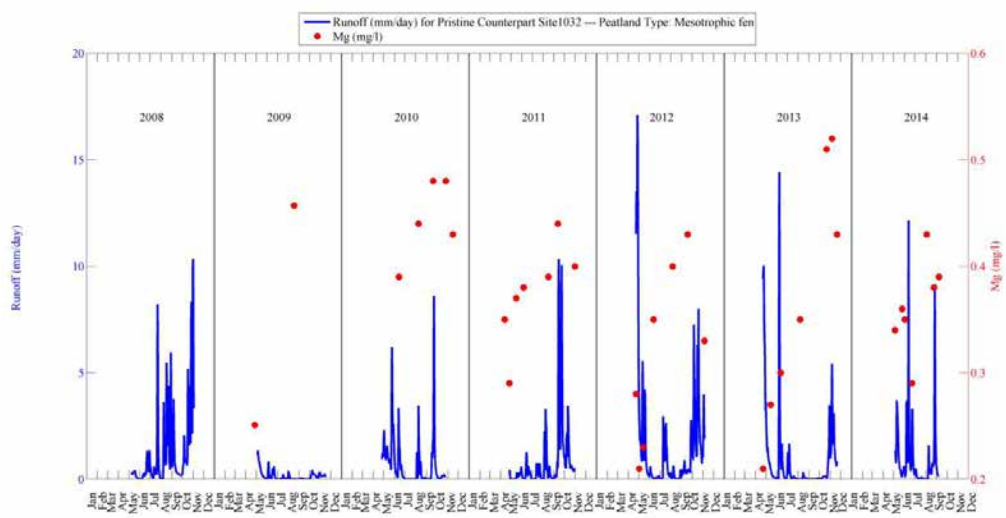
Runoff (mm/day) for Restored Site1031 --- Peatland Type: Mesotrophic fen
K (mg/l)
Date of Restoration (28.11.2011)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
K (mg/l)



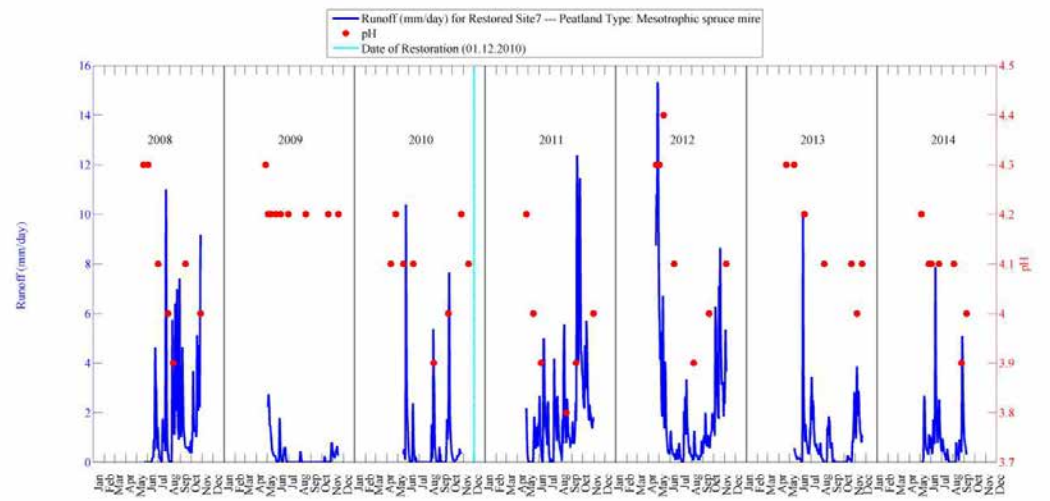
Runoff (mm/day) for Restored Site1031 --- Peatland Type: Mesotrophic fen
Mg (mg/l)
Date of Restoration (28.11.2011)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)

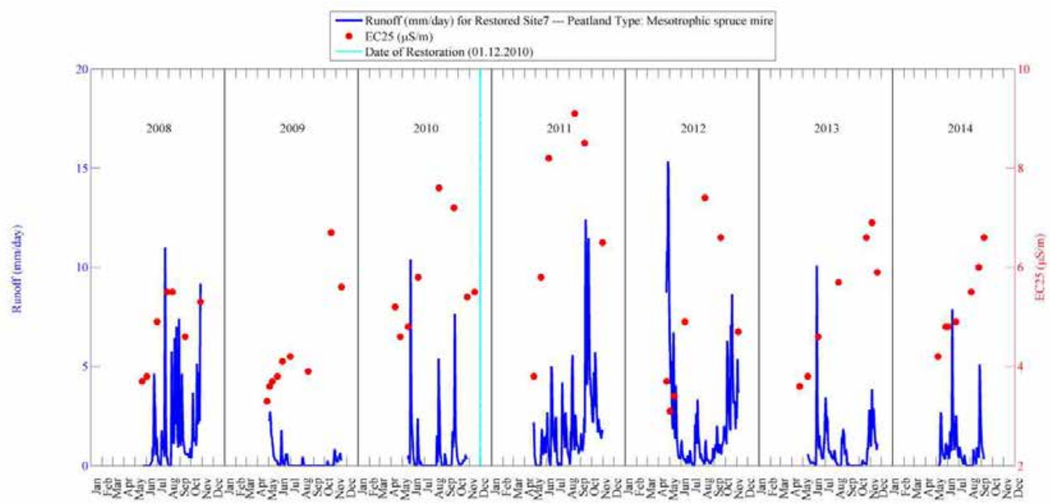

Runoff (mm/day) for Pristine Counterpart Site1032 --- Peatland Type: Mesotrophic fen
Ca (μ g/l)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
Ca (μ g/l)

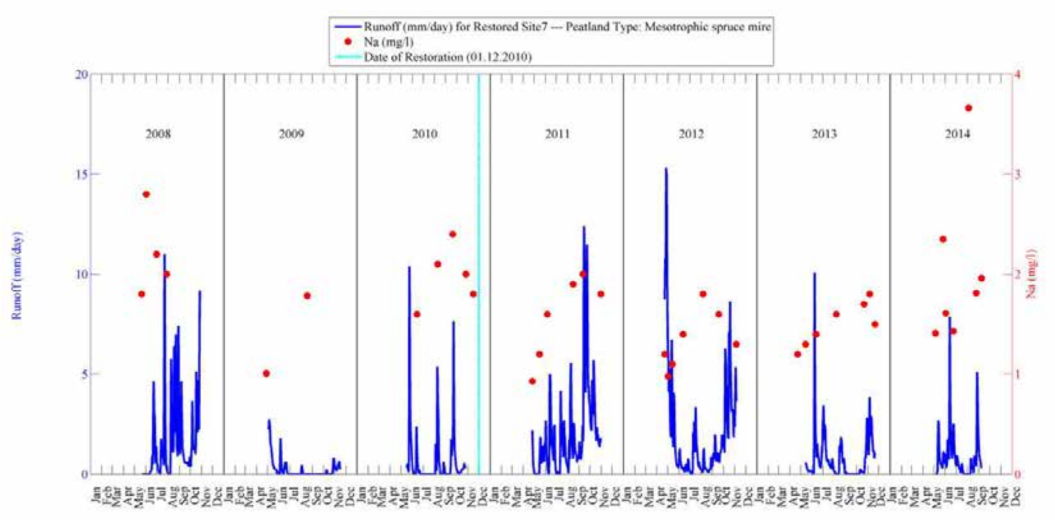

Runoff (mm/day) for Pristine Counterpart Site1032 --- Peatland Type: Mesotrophic fen
K (mg/l)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
K (mg/l)

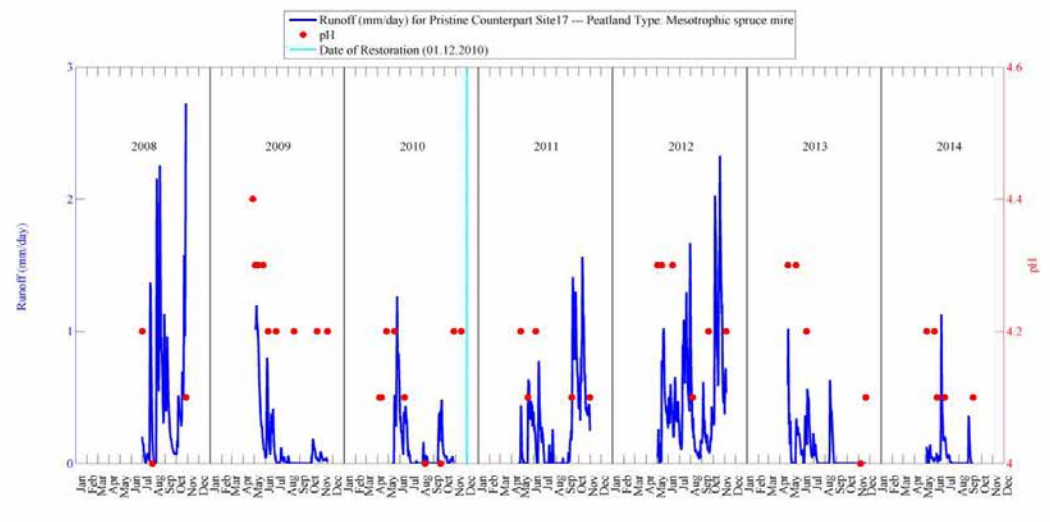

Runoff (mm/day) for Pristine Counterpart Site1032 --- Peatland Type: Mesotrophic fen
Mg (mg/l)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
Mg (mg/l)

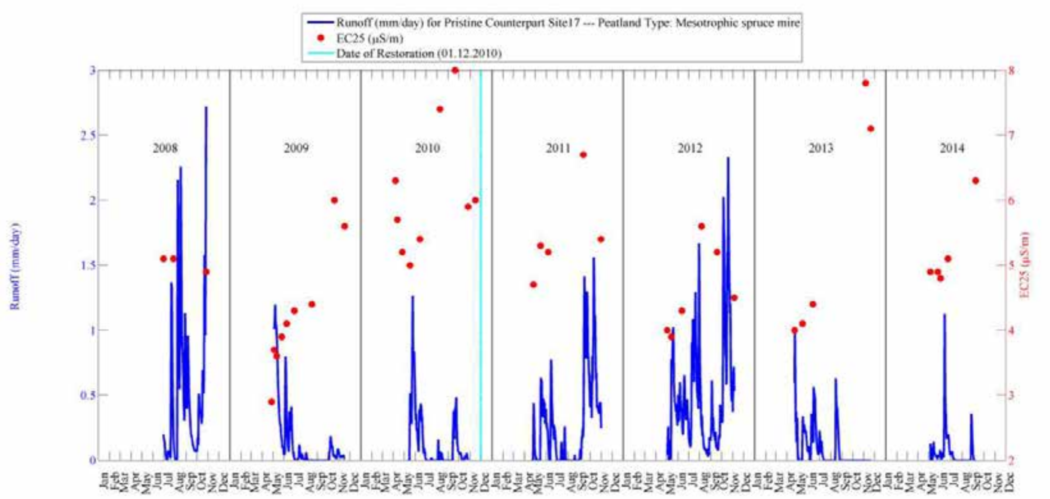
Appendix 7: Runoff (mm d^{-1}), pH, EC and Na concentrations of sites with continuous discharge monitoring in the years 2008-2014.

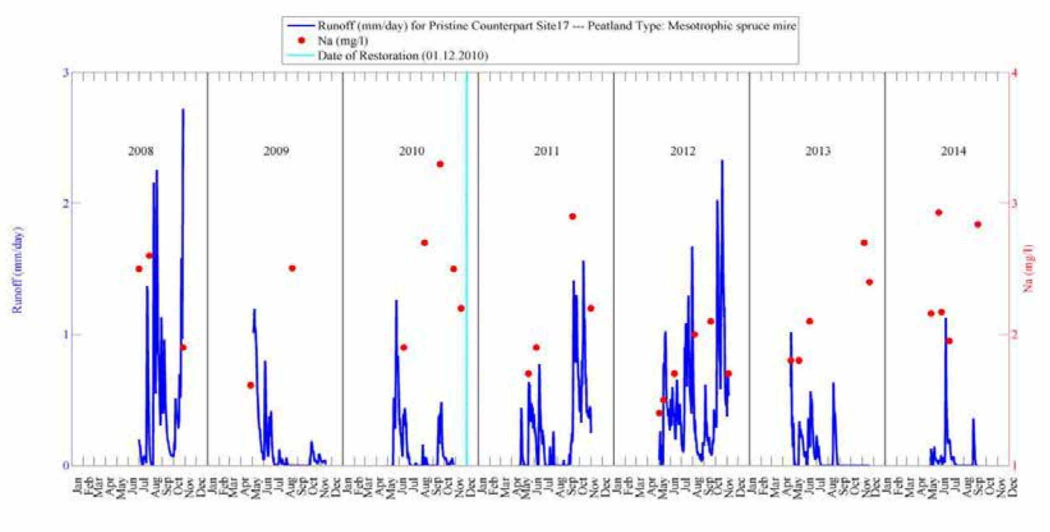


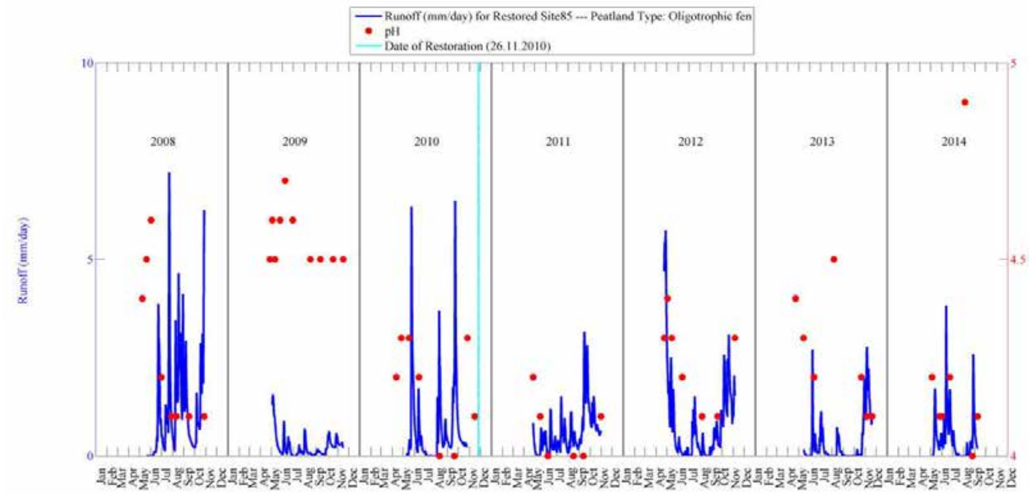




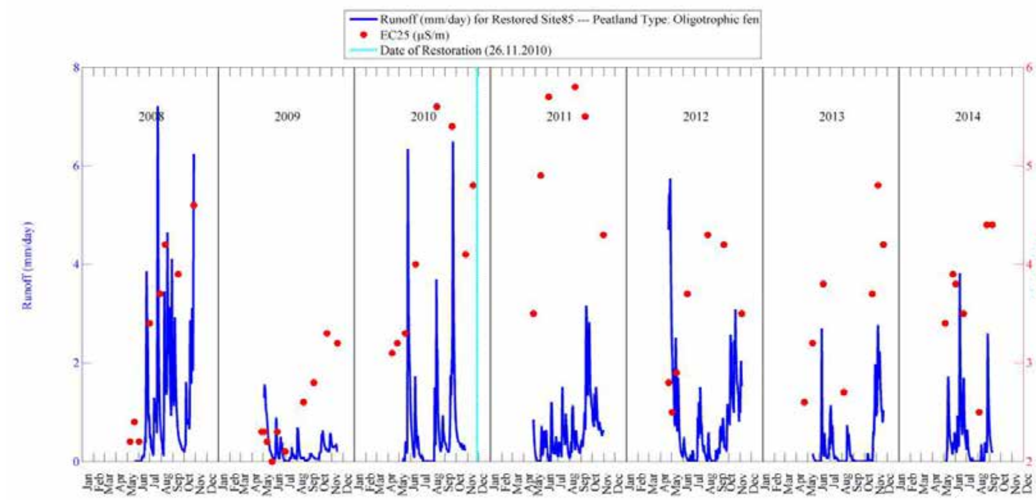

Runoff (mm/day) for Pristine Counterpart Site17 --- Peatland Type: Mesotrophic spruce mire
pH
Date of Restoration (01.12.2010)
Runoff (mm/day)
pH
2008
2009
2010
2011
2012
2013
2014

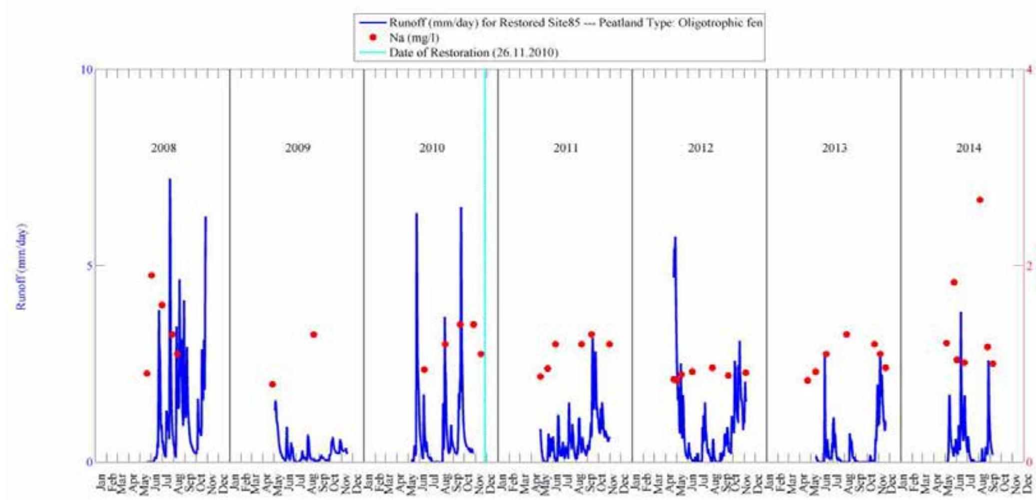

Runoff (mm/day) for Pristine Counterpart Site17 --- Peatland Type: Mesotrophic spruce mire
EC25 (µS/m)
Date of Restoration (01.12.2010)
Runoff (mm/day)
EC25 (µS/m)
2008
2009
2010
2011
2012
2013
2014

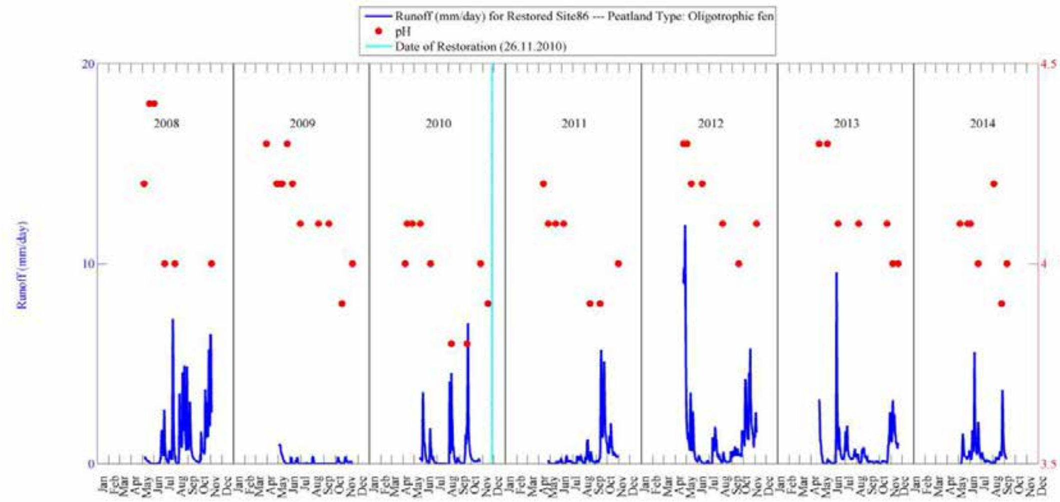

Runoff (mm/day) for Pristine Counterpart Site17 --- Peatland Type: Mesotrophic spruce mire
Na (mg/l)
Date of Restoration (01.12.2010)
Runoff (mm/day)
Na (mg/l)
2008
2009
2010
2011
2012
2013
2014

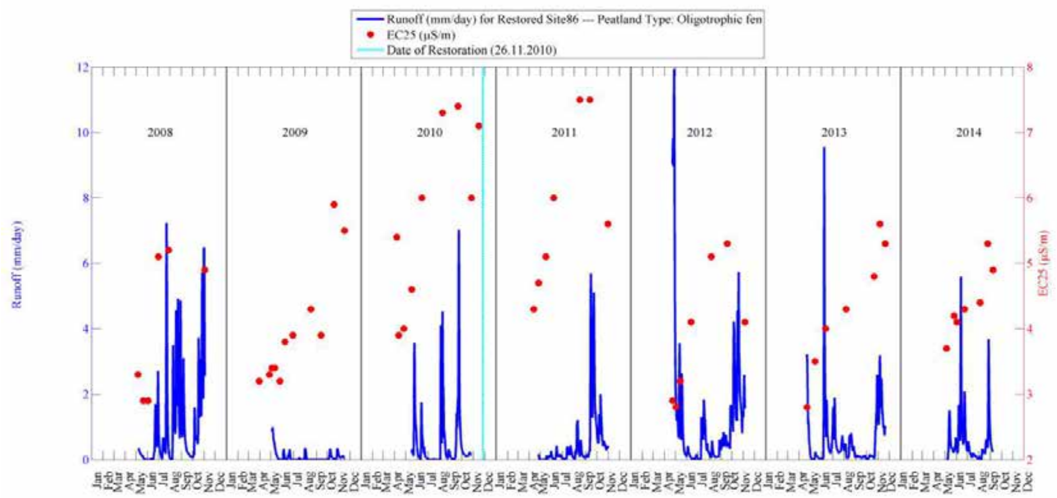

Runoff (mm/day) for Restored Site85 --- Peatland Type: Oligotrophic fen
pH
Date of Restoration (26.11.2010)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
pH

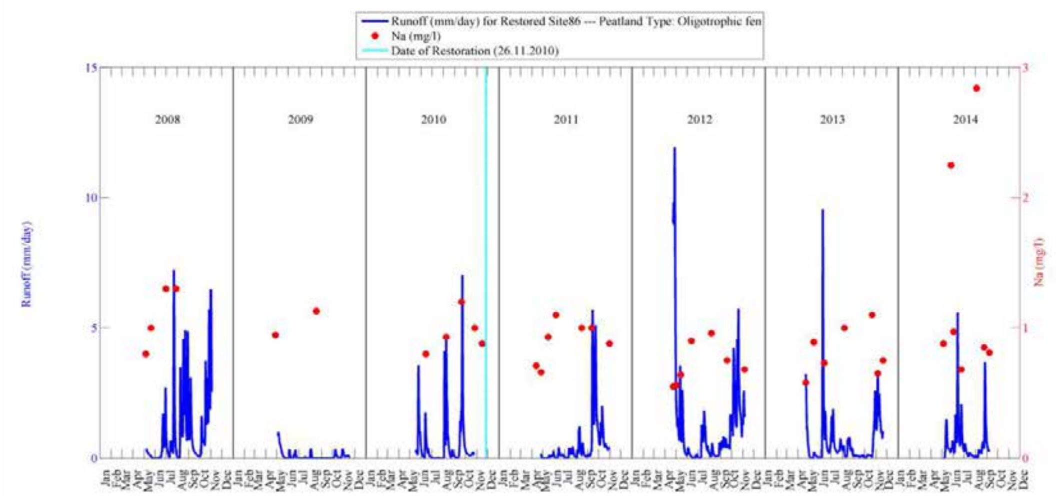
‘

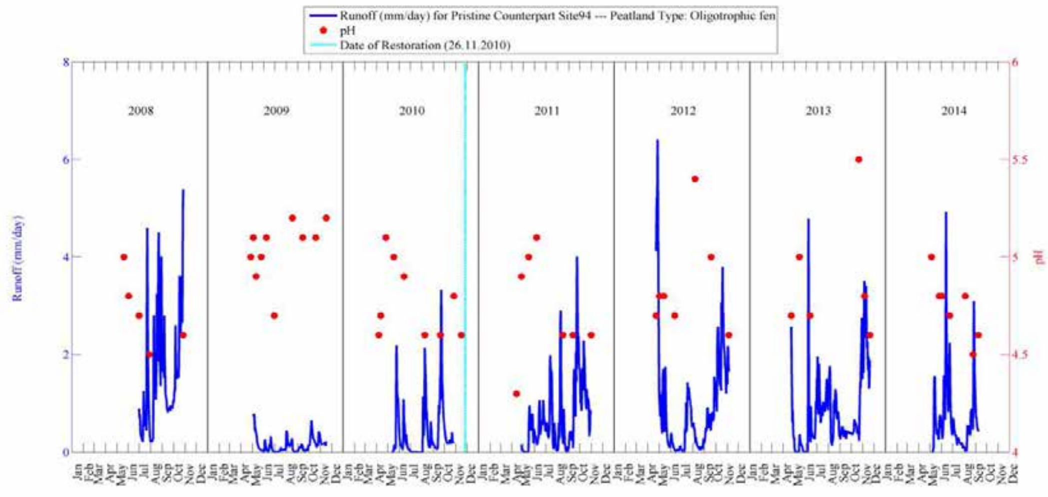

Runoff (mm/day) for Restored Site85 --- Peatland Type: Oligotrophic fen
EC25 (µS/m)
Date of Restoration (26.11.2010)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
EC25 (µS/m)

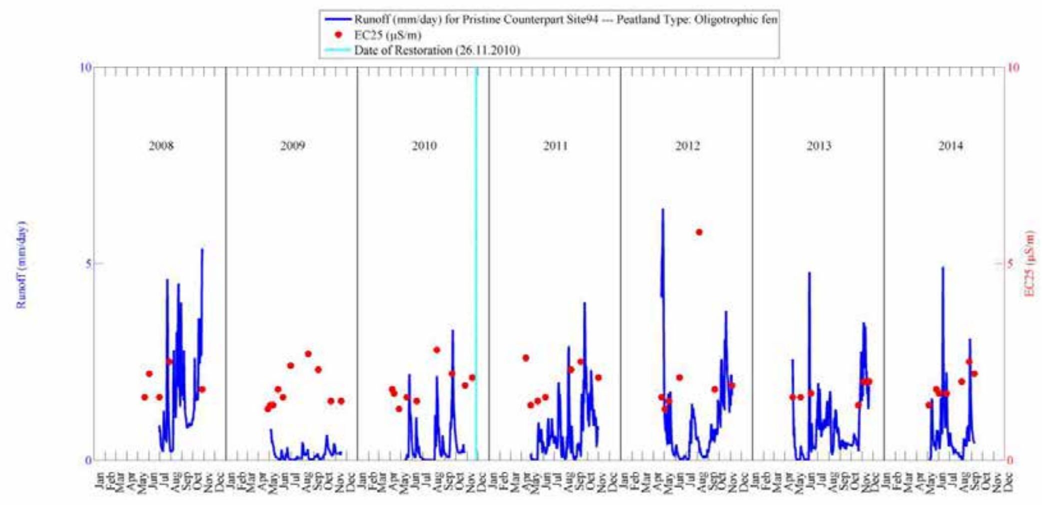

Runoff (mm/day) for Restored Site85 --- Peatland Type: Oligotrophic fen
Na (mg/l)
Date of Restoration (26.11.2010)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
Na (mg/l)

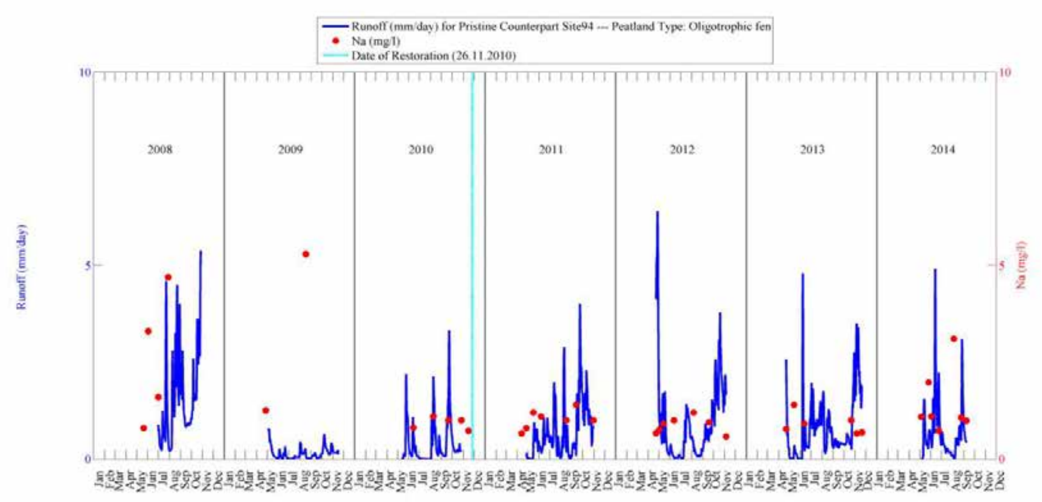

Runoff (mm/day) for Restored Site86 --- Peatland Type: Oligotrophic fen
pH
Date of Restoration (26.11.2010)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)

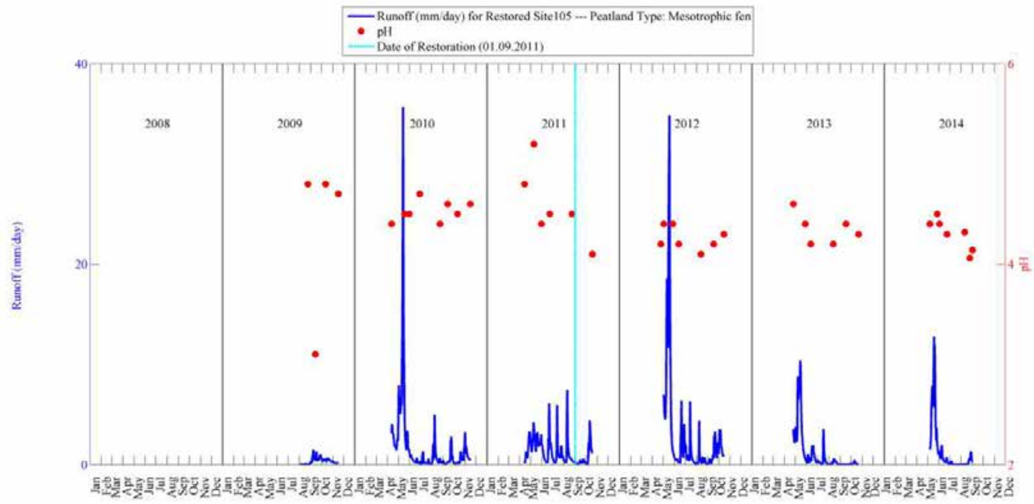

Runoff (mm/day) for Restored Site86 --- Peatland Type: Oligotrophic fen
EC25 (μS/m)
Date of Restoration (26.11.2010)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
EC25 (μS/m)


Runoff (mm/day) for Restored Site86 --- Peatland Type: Oligotrophic fen
Na (mg/l)
Date of Restoration (26.11.2010)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
Na (mg/l)

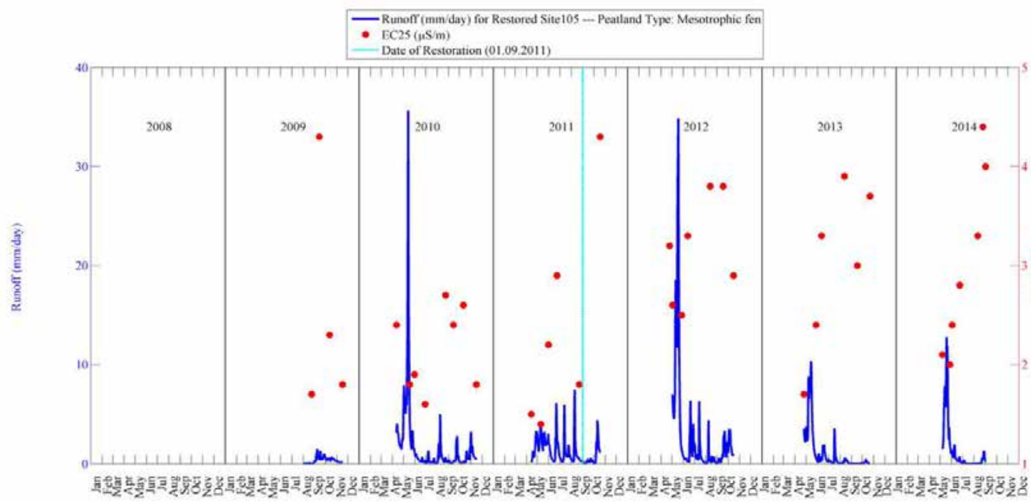

Runoff (mm/day) for Pristine Counterpart Site94 --- Peatland Type: Oligotrophic fen
pH
Date of Restoration (26.11.2010)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
pH


Runoff (mm/day) for Pristine Counterpart Site94 --- Peatland Type: Oligotrophic fen
EC25 (µS/m)
Date of Restoration (26.11.2010)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
EC25 (µS/m)

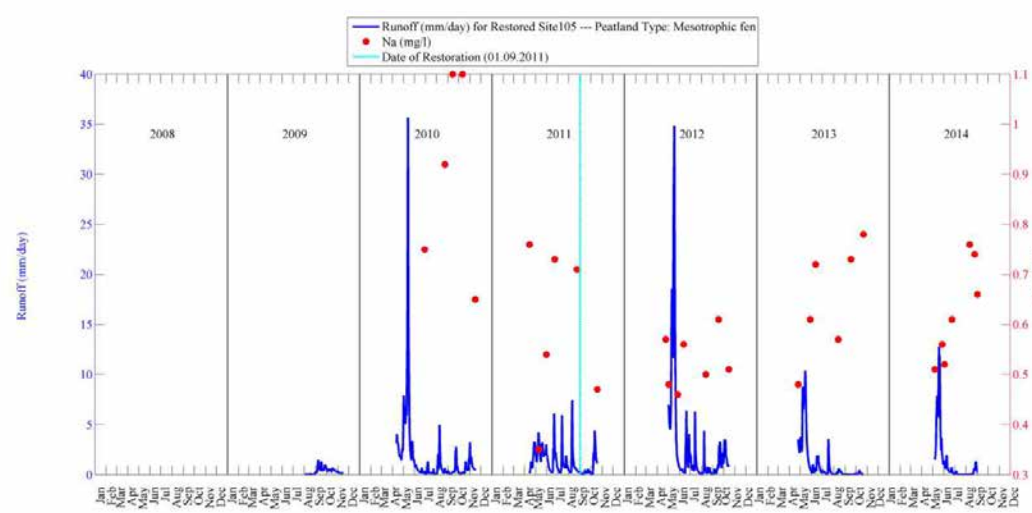

Runoff (mm/day) for Pristine Counterpart Site94 --- Peatland Type: Oligotrophic fen
Na (mg/l)
Date of Restoration (26.11.2010)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
Na (mg/l)



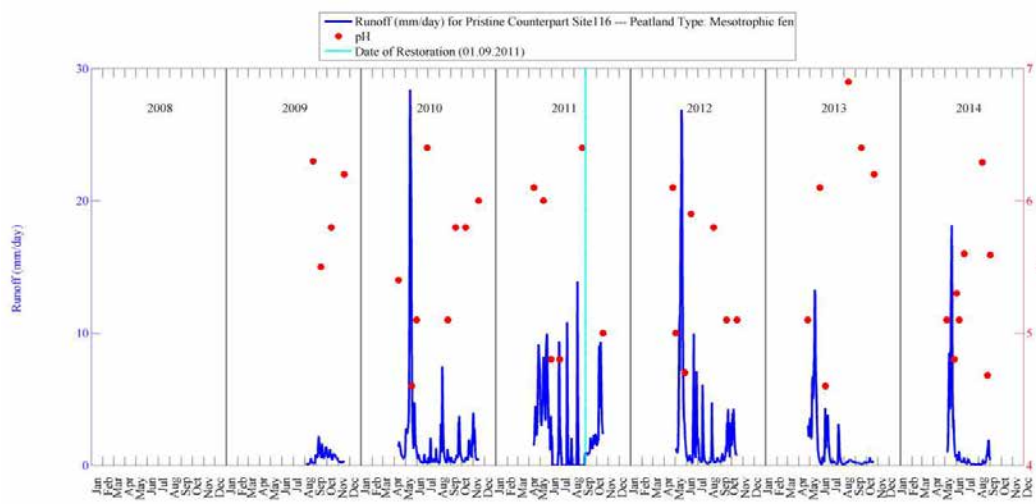
Runoff (mm/day) for Restored Site105 --- Peatland Type: Mesotrophic fen
pH
Date of Restoration (01.09.2011)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
pH

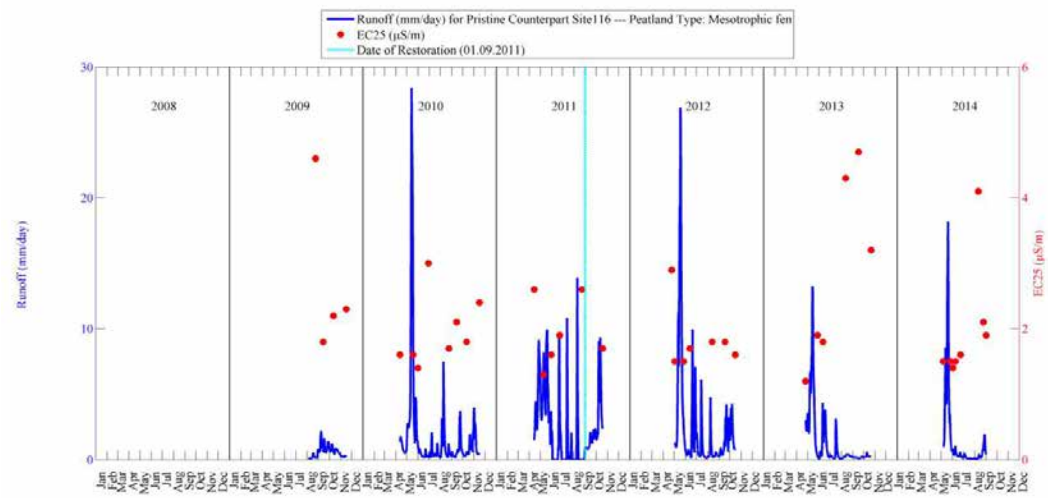


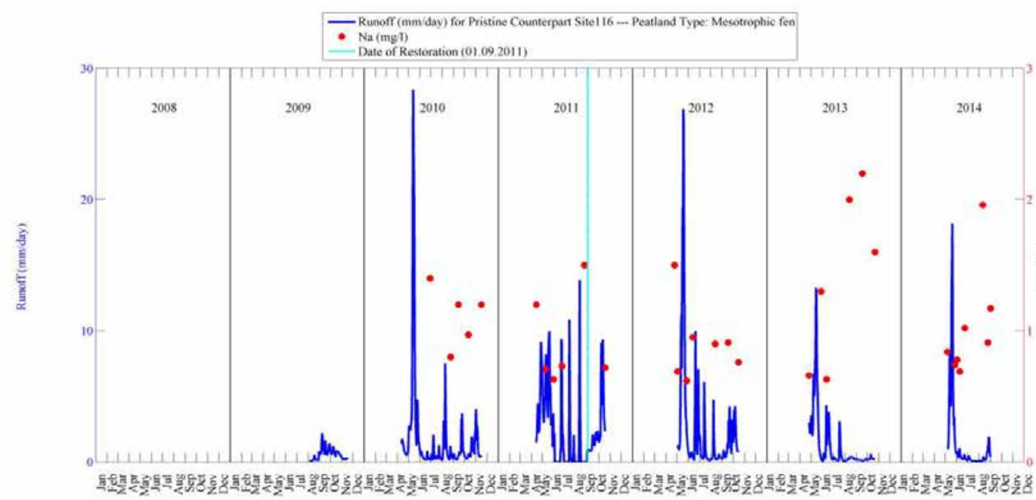
Runoff (mm/day) for Restored Site105 --- Peatland Type: Mesotrophic fen
EC25 (µS/m)
Date of Restoration (01.09.2011)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
EC25 (µS/m)

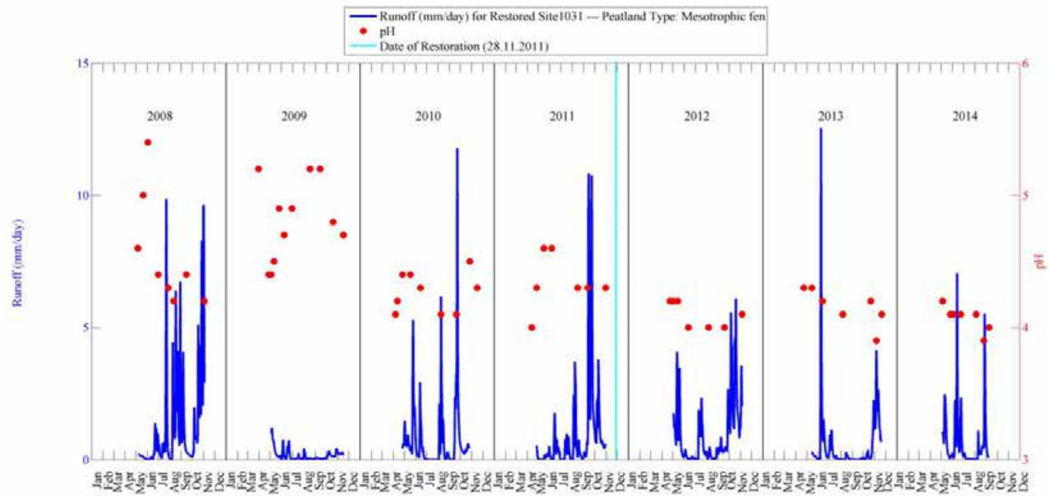


Runoff (mm/day) for Restored Site105 --- Peatland Type: Mesotrophic fen
Na (mg/l)
Date of Restoration (01.09.2011)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
Na (mg/l)

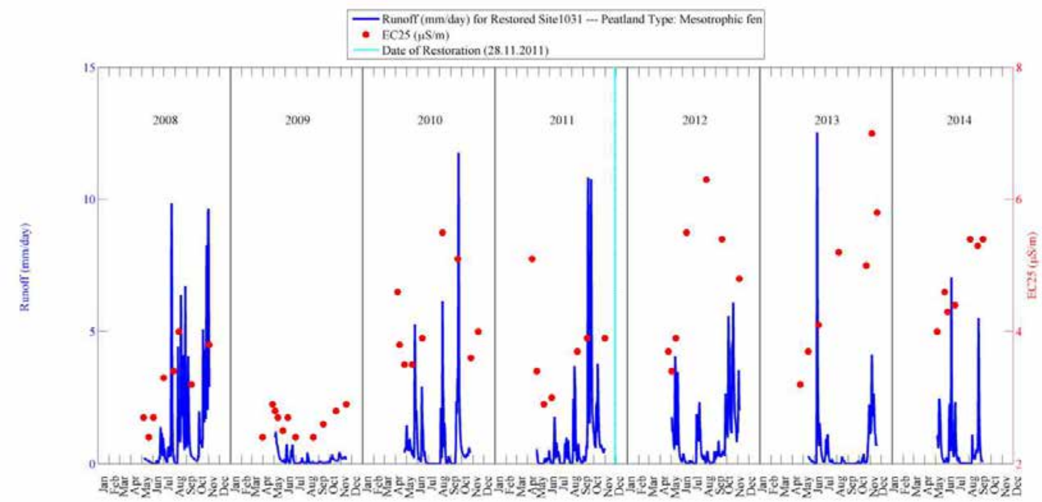

Runoff (mm/day) for Pristine Counterpart Site116 --- Peatland Type: Mesotrophic fen
pH
Date of Restoration (01.09.2011)
Runoff (mm/day)
pH
2008
2009
2010
2011
2012
2013
2014
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec


Runoff (mm/day) for Pristine Counterpart Site116 --- Peatland Type: Mesotrophic fen
EC25 (µS/m)
Date of Restoration (01.09.2011)
Runoff (mm/day)
EC25 (µS/m)
2008
2009
2010
2011
2012
2013
2014
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

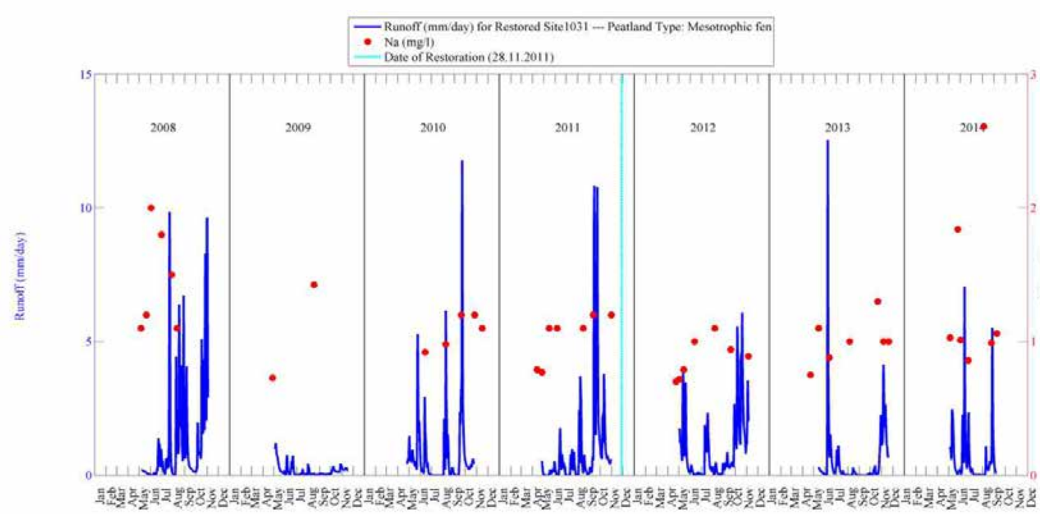

Runoff (mm/day) for Pristine Counterpart Site116 --- Peatland Type: Mesotrophic fen
Na (mg/l)
Date of Restoration (01.09.2011)
Runoff (mm/day)
Na (mg/l)
2008
2009
2010
2011
2012
2013
2014
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec



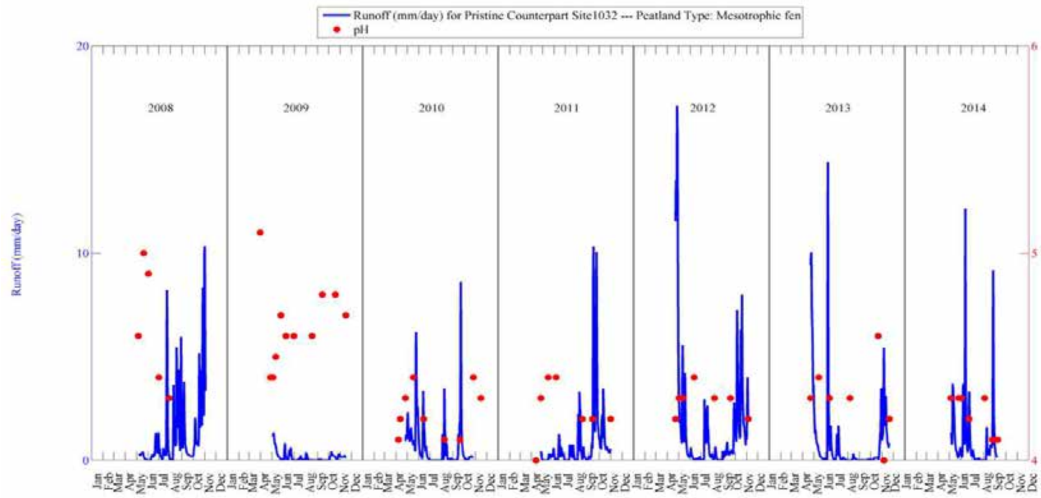
Runoff (mm/day) for Restored Site1031 --- Peatland Type: Mesotrophic fen
pH
Date of Restoration (28.11.2011)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
pH

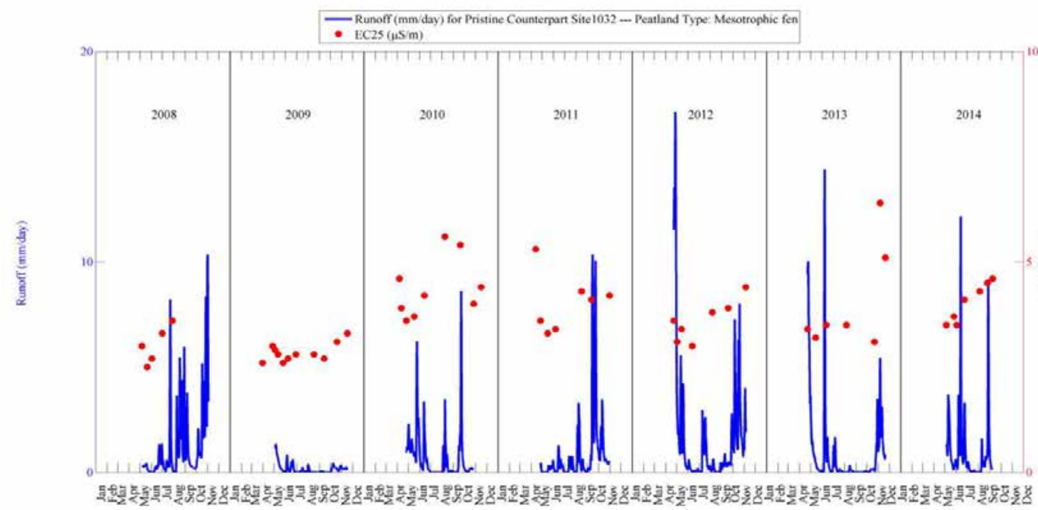


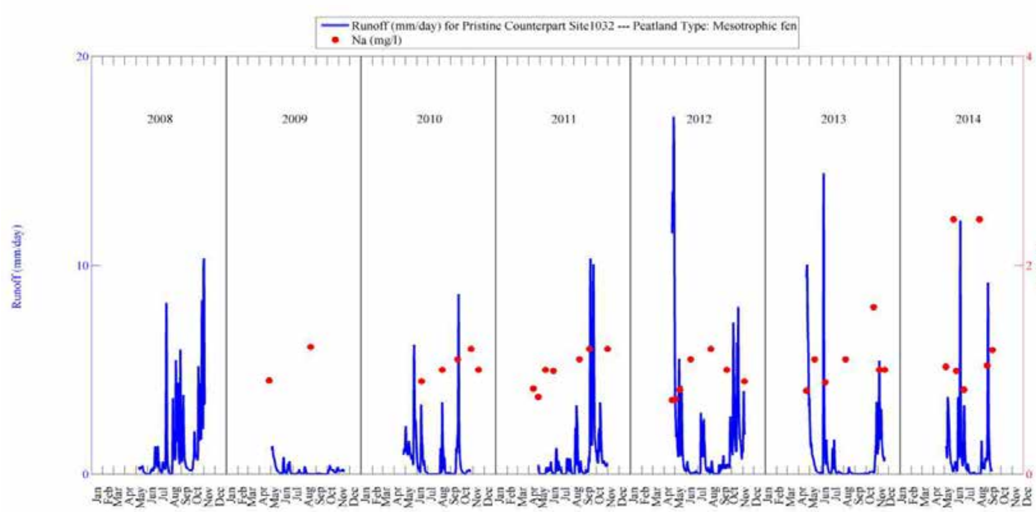
Runoff (mm/day) for Restored Site1031 --- Peatland Type: Mesotrophic fen
EC25 (µS/m)
Date of Restoration (28.11.2011)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
EC25 (µS/m)



Runoff (mm/day) for Restored Site1031 --- Peatland Type: Mesotrophic fen
Na (mg/l)
Date of Restoration (28.11.2011)
2008
2009
2010
2011
2012
2013
2014
Runoff (mm/day)
Na (mg/l)


Runoff (mm/day) for Pristine Counterpart Site1032 --- Peatland Type: Mesotrophic fen
pH
Runoff (mm/day)
pH
2008
2009
2010
2011
2012
2013
2014


Runoff (mm/day) for Pristine Counterpart Site1032 --- Peatland Type: Mesotrophic fen
EC25 (µS/m)
Runoff (mm/day)
EC25 (µS/m)
2008
2009
2010
2011
2012
2013
2014


Runoff (mm/day) for Pristine Counterpart Site1032 --- Peatland Type: Mesotrophic fen
Na (mg/l)
Runoff (mm/day)
Na (mg/l)
2008
2009
2010
2011
2012
2013
2014