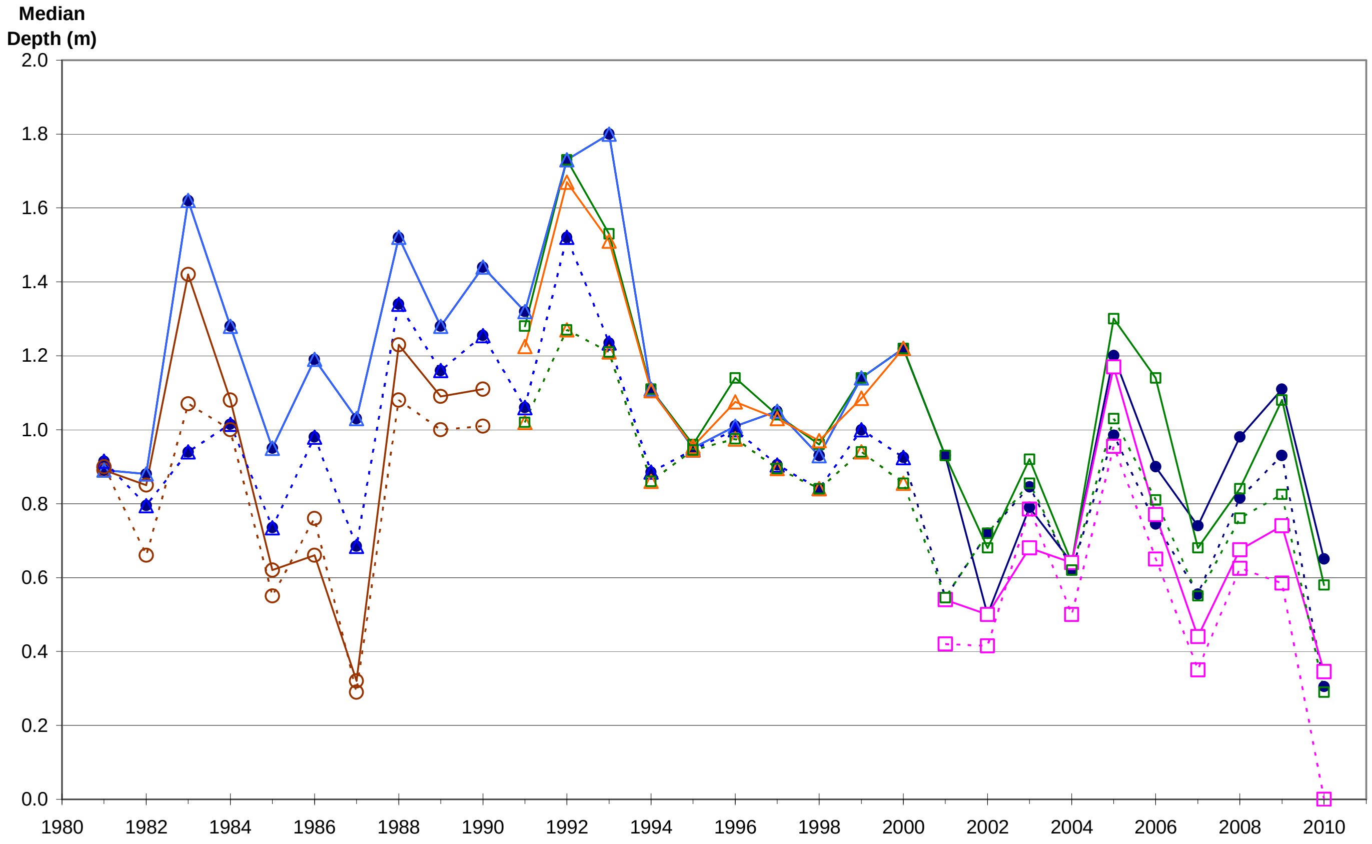
THIRTY YEAR (1981-2010) TRENDS IN DEPTHS AND RAINFALLS OF SOUTH-WESTERN AUSTRALIAN WETLANDS



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September 2015

Department of Parks and Wildlife

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Cover illustration: Median[1] September and November depths between 1981 and 2010 of 113 south-west Western Australian wetlands monitored under the WA Department of Parks and Wildlife's *South West Wetlands Monitoring Program* (SWWMP). The 12 graphed series are decadal (e.g. 1981-1990, 1991-2000) and multidecadal (e.g. 1981-2000, 1981-2010) groupings with 21–94 wetlands in each[2].

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1 These are the 'middle values', below and above which 50% of all depth values lie.
2 This cover illustration is a combination of Figures 1 & 2 of this report. See Section 3.1.

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SUMMARY

The water levels (depths) of a large number of wetlands in south-western Australia have been systematically monitored in September and November each year since the late 1970s under the Western Australian Department of Parks and Wildlife's (formerly Department of Environment & Conservation's) *South West Wetlands Monitoring Program* (SWWMP).

During this 30-plus-year period there have been significant year-to-year and longer-term variations in rainfalls and over most of the south-west there has been a significant downward trend. In this report we examine whether long-term trends exist in the depths of groups of south-western Australian wetlands and, if so, the extent to which these correlate with trends in rainfall.

The yearly September and November median depths of all SWWMP wetlands that were monitored every September or every November in each of the even 10, 20 and 30 year periods between 1981 and 2010 were calculated. These six decadal and multi-decadal periods were 1981-1990, 1981-2000, 1981-2010, 1991-2000, 1991-2010 and 2001-2010. The approach of splitting the 30 year (1981-2010) period of monitoring into a number of smaller periods was taken partly to examine trends over a number of periods of interest, but also because the set of wetlands monitored each year was not constant. Subdivision into shorter periods enabled data from many more wetlands to be utilised than would otherwise have been the case.

The statistical software package SAS 9.1.3 was used to analyse the September and November depth data for statistically-significant trends. Depth values were transformed to 'square root of depth' and PROC REG (a general purpose linear regression procedure) was used to examine trends in depth over time.

Monthly data from the Bureau of Meteorology were used to calculate the '12 months prior to September' and '12 months prior to November' rainfalls at the recording stations closest to each of the wetlands. These 'annual' falls were then analysed in similar manner to the depth data.

When graphed, the six September and six November depth median series (1981-1990, 1981-2000, etc.) showed considerable similarities in general appearance (direction of change from year to year and over longer periods) despite differences in wetland sample sizes and compositions. The series are therefore considered indicative of changes that have occurred at many wetlands throughout south-western Australia during 1981-2010. The general pattern has been a rise in median depths from 1981 to the early 1990s, followed by a fall in median depths to 2010.

Linear regression analyses of all depths (rather than depth medians) showed 'highly significant' ($p<0.01$) to 'very highly significant' ($p<0.001$) downward trends in September and November depths during 1981-2010 and 1991-2010, and 'significant' ($p<0.05$) downward trends in November depths during 2001-2010. There were no significant upward trends in depths over any of the time series.

The greatest rate of change in depths was the 'very highly significant' downward trend in September depths over the 20 years 1991-2010. This rate was −0.031 m/yr or −0.62m over the full period. November depths changed at a similar rate of −0.027 m/yr or −0.54m over the same period. The September and November rates of change over the 30 year period 1981-2010 were −0.014 m/yr and −0.010 m/yr respectively. These 'very highly significant' and 'highly significant' downward trends convert to −0.42m and −0.31m respectively over the full 30 year period.

The statistically significant downward trends in depths (five series) mostly (four series, these being the September and November depths of 1981-2010 and 1991-2010) coincided with statistically significant downward trends in rainfalls. The absence of significant trends in depths (seven series) mostly (six series) coincided with an absence of statistically significant trends in rainfall. There was thus a strong correlation between September and November depths and preceding 12 month rainfalls.

Over the 30 year period 1981-2010, the rates of decrease in September and November wetland depths were 6.8 times and 3.1 times the corresponding rates of decrease in preceding 12 month rainfalls. During the 20 year period 1991-2010, the rates of decrease in depths were 8.9 and 5.5 times the rates of decrease in rainfalls. These comparisons suggest that the continuing declines in rainfalls that have been predicted to occur over most of south-western Australia in coming decades will have a major impact on wetland water levels and, as a consequence, wetland biota and nature conservation, recreation and other values.

1. INTRODUCTION

Depths[1] of a large number of wetlands in south-western Australia have been systematically monitored in September and November each year since the late 1970s under the Western Australian Department of Parks and Wildlife's[2] *South West Wetlands Monitoring Program* (SWWMP) (Lane *et al.* 2004, 2015). During this 35+ year period there have been significant year-to-year and longer-term variations in rainfalls and over most of the south-west there has been a significant downward trend (Hope *et al.* 2015). Rainfall is one of a number of agents that may affect the water levels of individual SWWMP wetlands. In this report we examine whether long-term trends exist in the 1981[3]-2010 depths of various groupings of south-western Australian wetlands and, if so, the extent to which these correlate with trends in rainfall. This is a preliminary examination of the grouped data for long term trends. A detailed, descriptive statistical approach has been taken in order to guide, and provide a useful base for, further planned analyses.

2. METHODS

2.1 Depth data

The yearly September[4] and November[3] median depths and 10th, 25th, 75th and 90th percentiles of depths of all SWWMP wetlands that were monitored every September or every November in each of the 'even' 10, 20 and 30 year periods between 1981 and 2010 were calculated and the results graphed. These six decadal and multi-decadal periods were 1981-1990, 1981-2000, 1981-2010, 1991-2000, 1991-2010 and 2001-2010. A Table showing which wetlands were monitored every September and every November in each time period is provided in Appendix 67.

The approach of splitting the 30 year period of monitoring into a number of smaller periods was taken partly to examine trends over a number of periods of interest, but also because the set of wetlands monitored each year was not constant between 1981 and 2010. The set was large (up to 119 wetlands) in the early 1980s, at a minimum (55) in the early 1990s and substantially higher again (100 wetlands) by 2000 (Lane *et al.* 2004). In addition to these changes in numbers, there were changes in the composition of the set being monitored. Thus, at various times, some wetlands were added to the program while monitoring of others was simultaneously discontinued[5]. As a consequence, many wetlands were monitored in all years of 1981-1990 and 2001-2010, but relatively few in all years of 1991-2000, and even fewer in all years of the multi-decadal periods 1981-2000, 1981-2010 and 1991-2010. The subdivision of 1981-2010 into shorter, multiple, overlapping periods for analysis enabled data from many more wetlands to be utilised than would have been the case if analysis had been restricted to the 21-28 wetlands (see Table 1) monitored in all years from 1981 to 2010.

Table 1. Number of wetlands and rainfall recording stations in each time series.

Month	1981-1990	1981-2000	1981-2010	1991-2000	1991-2010	2001-2010
September	65	21	21	28	27	90
November	69	28	28	36	36	94
% difference	6%	33%	33%	29%	33%	4%

1 In this report the terms 'depth' and 'water level' are used interchangeably. While, strictly speaking, it is the water level that is monitored, the staff gauge datum (i.e. 0.00m) is the bed level at the deepest location in the wetland. Water level readings therefore indicate, and are equal to, depth at the deepest location.

2 DPaW commenced operations on 1 July 2013 following the separation of the former Department of Environment and Conservation (DEC) into DPaW and the Department of Environment Regulation. DEC's predecessors in regard to SWWMP were the Department of Conservation and Land Management (CALM; 1985-2006) and the Department of Fisheries and Wildlife (pre-1985).

3 Limited use is also made of 1980 depth data. See Section 3.8.

4 September depths were measured during the nine day period commencing on the second Saturday of the month. Dates of measurement could therefore vary from 8th to 22nd September. November depths were measured during the nine day period commencing on the first Saturday of the month and these dates could vary from 1st to 15th of the month. See Appendix 93 for more detail.

5 These changes in number and composition were primarily due to changes in the purpose and funding of SWWMP. See Section 2of Lane *et al.* (2004) for the history.

The statistical software package SAS 9.1.3 (for Windows) was used to analyse the September and November depth data from each of the above six periods for statistically-significant trends. The depth data were imported into SAS on the Department's SAS Server (KENS-APP-180) via a remote desktop connection.

Depth values were transformed to 'square root of depth' as this transformation resulted in more-normally-distributed residuals in the linear regression analysis. PROC REG was used to examine trends in depth over time. This is a general purpose linear regression procedure which uses the principle of least squares to produce estimates that are the best linear unbiased estimates under classical statistical assumptions. The model used was 'sqrt(depth) = time', with 'time' being the number of months elapsed since 01 January 1977 (as in Lane *et al.* 2004). The procedure's output provided parameter estimates (slope & intercept) of sqrt(depth) over time and calculated a two-tailed significance probability (p value). The sign of the slope parameter determined if the trend in depth over time was increasing (+ve slope) or decreasing (-ve slope). The levels of significance that were adopted were $p \geq 0.05$ = 'not significant', $p < 0.05$ = 'significant', $p < 0.01$ = 'highly significant' and $p < 0.001$ = 'very highly significant'[1]. These regression equations, and the individual depths from which they had been calculated, were also graphed (Appendices 25-36) and the rates of change in depth over time were determined where trends were statistically significant (Appendix 70).

2.2 Rainfall data

Monthly rainfall data were downloaded from the Bureau of Meteorology's website (www.bom.gov.au) for the rainfall recording stations (one per wetland) that were closest to each of the wetlands. In cases where there were significant gaps in the data for the 30 year period of interest (1981 to 2010), data from the next-closest recording stations with adequate data were utilised[2]. Annual rainfall was then calculated for the 12 months prior to September (i.e. September to August inclusive) and the 12 months prior to November (i.e. November to October inclusive) and graphed and analysed in similar manner to the corresponding depth data. The authors considered totalling the rainfall data for the 12 months prior to the exact date on which each wetland depth was measured as this could perhaps have strengthened the correlations between annual rainfall and depths, however this was considered too time-consuming and not essential for the purposes of this report. Information regarding the nature of monthly rainfall data, and the daily data on which it is based, may be obtained from the Bureau of Meteorology website.

The SAS model used for determination of trends in rainfall was 'totrain = time', with 'time' being the number of months elapsed since 01 January 1977, as in the depth data analyses. The same levels of significance as for the depth data were adopted. The regression equations, and the individual rainfall values from which they had been calculated, were graphed (Appendices 37-48) and the rates of change in rainfall over time were determined where trends were statistically significant (Appendix 70)[1].

Tables of all the rainfall recording stations of this report, their distances from corresponding wetlands and other related information are presented in Appendices 68-69.

2.3 Wetland and rainfall recording station locations

Maps (Appendices 53-64) were prepared showing the geographic distribution (locations) of the wetlands within each of the periods of analysis. These were prepared to assist in interpretation of the results as the distribution of monitored wetlands varied between periods due to changes in the number and composition of wetlands being monitored over time (see Section 2.1). These maps also effectively depict the distribution of the rainfall recording stations referred to in Section 2.2, as most of these stations are less than 20 km from their corresponding wetlands (Appendix 69). The average distance is approximately 15km; only six are more than 35 km and the greatest distance is 52 km. Thesde maps may be usefully compared with the 12 monthly rainfall decile and rainfall anomaly maps of Appendices 71-82 and those of Appendices 83-86.

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[1] The Microsoft Excel software used to generate the medians and percentiles of depth and rainfall also produced a regression or trend line (equation) for each of the medians (50th percentiles), however it did not generate 'p' values for these equations and therefore could not be used to assess their statistical significance. These lines and equations appear in Appendices 1-24, however they have not been used elsewhere in this report.

[2] If these analyses are repeated in the future, it may be preferable to use interpolated data (i.e. 'patched' SILO data, available from the Government of Queensland's Department of Science, Information Technology, Innovation and the Arts, at http://www.longpaddock.qld.gov.au/silo/data_available.html) rather than data from alternative rainfall recording stations.

3. RESULTS

3.1 Trends in September and November <u>depth medians</u> between 1981 and 2010

Figure 1 (*September depth medians*[1]) and Figure 2 (*November depth medians*[1]) show[2]:

- Considerable similarities in general appearance (especially direction of change from year to year and over longer periods) of all 12 graphed series within the two Figures, despite differences[3] in sample sizes and compositions.
- A general pattern of rise in median depths to 1992-1993, followed by a sharp fall in 1994 and then a decline to historic or near-historic lows in 2010, with at least two pronounced troughs in intervening years.
- An apparent 'regime change' between 2000 and 2001, with September and November depth medians being mainly below 1.0m and 0.8m respectively from 2001 to 2010.

The above patterns and associated trends are of primary interest and are explored at length in later sections of this report.

Figures 1 & 2 also show several other noteworthy features. These are briefly examined here for convenience and are as follows:

- Generally-lower median depths in the first (1981-1990) and last (2001-2010) series than in the same periods (1981-1990 and 2001-2010) of the other directly-comparable series (i.e. 1981-2000, 1981-2010 and 1991-2010). This could be a consequence of the additional[4] wetlands of the first and last series ($65 \leq n \leq 94$; see Table 1) being morphologically shallower (as a group) than the wetlands of the other series ($21 \leq n \leq 36$), or these additional wetlands experiencing 'drier conditions' (essentially less rainfall) than the wetlands of the other series, or a less-than-straightforward combination of elements of both.
- A pronounced peak in September median depths in 1983, due in particular to the flooding effects of a rain-bearing depression (ex-tropical cyclone) in January 1982, followed by an unusually wet winter in 1983 (Appendix 85)[5]. These rains affected the inland agricultural region in particular, an area that includes a significant proportion of the wetlands in each of the three relevant series (see wetland distribution maps in Appendices 53-55). Some of these wetlands had 'unsustainably high' water levels (i.e. water levels above their normal cease-to-flow levels) in September 1983. These experienced greater than normal falls in water levels from September to November (Lane *et al.* 2015), partially explaining the absence of a pronounced peak in the November depth median. The lack of a November 1983 peak is also partly because the additional wetlands in the November series contained a greater proportion of shallower / drier wetlands than the additional wetlands of the September series.
- Exceptionally low median depths in September 1987 of the 1981-1990 time series, but not in September 1987 of the 1981-2000 and 1981-2010 time series. In this case the disparity is at least in part due to many of the additional wetlands in the 1981-1990 series being in an area of the south west that was particularly drought-affected in 1987 (see Appendices 53-55 and rainfall distribution maps of Appendices 71, 77 & 83).

In relation to the three dot points immediately above, and more generally, it should be noted that November series comprise 4% to 33% more wetlands than their corresponding

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1 These 12 median (50th percentile) depth series are also shown individually in Appendices 1-12, together with their corresponding 10th, 25th, 75th and 90th percentile series and median depth regression (trend) lines, equations and R^2 values. Note that these regressions are of median depths, not individual wetland depths as in Section 3.2.

2 For convenience, all Figures have been grouped together, and commence at page 20.

3 Except the 1981-2000 and 1981-2010 series (Sep & Nov), which have identical sample sizes and compositions each year to 2000, and the 1991-2000 and 1991-2010 series (Nov only), which also have identical sample sizes and compositions each year to 2000.

4 Note that the wetlands of the'other directly-comparable series' are subsets of the first and last series.

5 Note that these significant rain events are not apparent from the '12 months prior to …' graphs (Figures 5 & 6).

September series[1] and same-year (i.e. Sept to Nov) differences between the depth median series may therefore be due in part – in some cases in large part – to differences in the number and composition of wetlands in each series. For a list of the wetlands in each series see Appendix 67 and for maps of their distributions see Appendices 53-64.

3.2 Trends in September and November depths between 1981 and 2010

Linear regression equations ('trend lines') have been calculated using all September and November depths (not simply depth medians as in Section 3.1) in each of the six periods referred to above (1981-1990, 1981-2000, 1981-2010, 1991-2000, 1991-2010 and 2001-2010). The resultant 12 trend lines have been plotted in Figures 3[2] & 4[2]. These show 'very highly significant' ($p<0.001$) or 'highly significant' ($p<0.01$) downward trends in September depths and November depths of 1981-2010 and 1991-2010, and a 'significant' ($p<0.05$) downward trend in November depths of 2001-2010. There are no significant upward trends in September or November depths during any of the six decadal and multi-decadal periods between 1981 and 2010.

The greatest rate of change in depths is the 'very highly significant' downward trend in September depths over the 20 years 1991-2010 (Table 2). This rate is −0.031 metres per year or −0.62 metres over the full period. November depths changed at a similar rate of −0.027 metres per year or −0.54 metres over the same period.

The September and November rates of change over the 30 year period 1981-2010 were −0.014 m/yr and −0.010 m/yr respectively. These 'very highly significant' and 'highly significant' downward trends convert to −0.42 metres and −0.31 metres respectively over the full 30 year period.

Table 2. Trends in September and November depths over 10, 20 and 30 year periods between 1981 and 2010.
(n = number of wetlands; **Very Highly Significant** and **Highly Significant** trends are in bold).

Period	Years	n	P value	Significance of Trend (ns = not significant)	Direction of Trend	Rate of Change (m/yr)	Change over Period (m)
1981-1990 September	10	65	0.5819	ns			
1981-1990 November	10	69	0.1936	ns			
1981-2000 September	20	21	0.8402	ns			
1981-2000 November	20	28	0.2836	ns			
1981-2010 September	30	21	**0.0001**	**Very Highly Significant**	**Decreasing**	**−0.014**	**−0.42**
1981-2010 November	30	28	**0.0017**	**Highly Significant**	**Decreasing**	**−0.010**	**−0.31**
1991-2000 September	10	28	0.2442	ns			
1991-2000 November	10	36	0.0760	ns			
1991-2010 September	20	27	**<0.0001**	**Very Highly Significant**	**Decreasing**	**−0.031**	**−0.62**
1991-2010 November	20	36	**<0.0001**	**Very Highly Significant**	**Decreasing**	**−0.027**	**−0.54**
2001-2010 September	10	90	0.0634	ns			
2001-2010 November	10	94	0.0281	Significant	Decreasing	−0.022	−0.22

[1] This is due to a number of factors including depth monitoring of some wetlands commencing in November (not September) of 1981, access to depth gauges being more-frequently prevented by flooding in Septembers than in Novembers, and some gauge-reading volunteers having difficulty meeting routine monitoring period time constraints in Septembers of the early 1980s (while all monitoring in other periods was done by SWWMP personnel).

[2] They are also shown individually, together with the regression equations, R^2 values, precise 'p' values and plotted depths of each individual wetland, in Appendices 25-36.

3.3 Trends in '12 months prior to September' and '12 months prior to November' rainfall medians between 1981 and 2010

Figure 5 ('*12 months prior to September' rainfall medians*[1]) and Figure 6 ('*12 months prior to November' rainfall medians*[1]) show:

- Considerable similarities in general appearance (especially direction of change from year to year and over longer periods) of all 12 graphed series within the two Figures, despite differences[2] in sample sizes and compositions.
- A lack of visually-pronounced long term trends in the 12 graphed series, although '12 months prior to September' rainfall medians do appear somewhat lower during the period 2001 to 2010, due to the absence of pronounced peaks and the presence of two particularly low troughs.
- Pronounced peaks in median rainfalls (all series considered collectively) in 1988, 1992 and 1999 in particular.
- Pronounced troughs in median rainfalls (all series considered collectively) in 1987, 1994, 2001 and 2010 in particular.

Note that the first (1981-1990) and last (2001-2010) '12 months prior to September' and '12 months prior to November' series comprise many more recording stations (65-94) than the other rainfall series (21-36 recording stations) (see Table 1). Note also that the '12 months prior to November' series comprise 4% to 33% more rainfall recording stations than the corresponding '12 months prior to September' series. Same-year differences between the rainfall median series may therefore be due in part – in some cases in large part – to differences in the number and composition of rainfall recording stations (one per wetland) in each series. For lists of the rainfall recording stations in each series see Appendix 68 (a&b).

Note that the distribution of the rainfall recording stations within each of the 12 graphed series is essentially the same as for the corresponding series of wetlands (see maps at Appendices 53-64) since each rainfall recording station was selected (Section 2.2) on the basis of being close to a wetland of the corresponding series. The map (Appendix 53) of 1981-1990 September wetland locations, for example, also serves to indicate the approximate locations of rainfall recording stations in the 1981-1990 '12 months prior to September' rainfall series.

To see the distribution of rainfall across the entire south-west (i.e. from north of Geraldton to east of Esperance) each 'year' ('12 months prior to Sept' and '12 months prior to Nov') from 1981 to 2010, refer to Appendices 71-76 (rainfall decile maps) and 77-82 (rainfall anomaly maps). These maps show, for example, that in the 12 months prior to Sept 2001 (first maps of Appendices 73 & 79) virtually all of the south-west was in drought, with a large area of 'lowest on record' rainfalls and deficits up to and exceeding 400mm. The maps also show that it is quite common for some parts of the south-west to have substantially lower than average rainfalls while other parts have substantially above average rainfalls. In the 12 months prior to Sept 1993 (third maps of Appendices 72 & 78), for example, the west coast was mainly in drought while the south-east coast experienced much higher than average falls.

3.4 Trends in '12 months prior to September' and '12 months prior to November' rainfalls between 1981 and 2010

Linear regression equations ('trend lines') have been calculated using all September[3] and November[3] rainfalls (not simply rainfall medians as in Section 3.3) in each of the six periods referred to above (1981-1990, 1981-2000, 1981-2010, 1991-2000, 1991-2010 and 2001-2010). The resultant 12 trend lines have been plotted in Figures 7[4] & 8[4]. These show 'very highly significant' ($p<0.001$) or 'highly significant' ($p<0.01$) downward trends in September and November rainfalls of 1981-2010 and November rainfalls of 1991-

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[1] These 12 median (50th percentile) rainfall series are also shown individually in Appendices 13-24, together with the corresponding 10th, 25th, 75th and 90th percentile series and median rainfall regression (trend) lines, equations and R^2 values. Note that these regressions are of median rainfalls, not individual rainfalls as in Section 3.4..

[2] Except the 1981-2000 and 1981-2010 series (Sep & Nov), which have identical sample sizes and compositions each year to 2000, and the 1991-2000 and 1991-2010 series (Nov only), which also have identical sample sizes and compositions each year to 2000.

[3] Throughout this Section (3.4), reference to 'September' and 'November' rainfalls should be interpreted as '12 months prior to September' and '12 months prior to November' respectively.

[4] They are also shown individually, together with the regression equations, R^2 values, precise 'p' values and plotted rainfalls at each individual recording station, in Appendices 37-48.

2010, and a ‘significant’ ($p<0.05$) downward trend in September rainfalls of 1991-2010. There is also a significant *upward* trend in September rainfalls in 2001-2010. This is the only significant upward trend in rainfall (there were none in depths, see Section 3.2) during any of the six decadal and multi-decadal periods between 1981 and 2010.

The greatest rate of change in rainfall was the ‘significant’ upward trend in September rainfalls over the 10 years 2001-2010 (Table 3). This rate was 6.2 millimetres per year, or 62.2 mm over the full period. The greatest rate of decrease in rainfall was the ‘very highly significant’ downward trend in November rainfalls over the 20 years 1991-2010. This rate was −4.9 mm/yr, or −98.9 mm over the full period.

The September and November rates of change over the 30 year period 1981-2010 were −2.1 and −3.4 mm/yr respectively. These ‘highly significant’ and ‘very highly significant’ downward trends convert to −61.9 mm and −101.2 mm respectively over the full 30 year period.

Note that the downward trend in September rainfalls in 1991-2010, though not as statistically significant as the trend over the period 1981-2010, has a higher rate of change (−3.5 mm/yr in 1991-2010, compared with −2.1 mm/yr in 1981-2010).

It is important to remember that 1981-1990, 1981-2000, etc., are arbitrary periods. A choice of longer or shorter periods or different starting and finishing years could produce stronger or weaker trends, both positive and negative. This observation applies, of course, to the analysis of both rainfall and wetland depth trends.

Table 3. Trends in ‘12 months prior to September’ and ‘12 months prior to November’ rainfalls over 10, 20 and 30 year periods between 1981 and 2010 (n = number of wetlands; **Very Highly Significant** and **Highly Significant** trends are in bold).

Period	Years	n	P value	Significance of Trend (ns = not significant)	Direction of Trend	Rate of Change (mm/yr)	Change over Period (mm)
1981-1990 September	10	65	0.4511	ns			
1981-1990 November	10	69	0.1738	ns			
1981-2000 September	20	21	0.3855	ns			
1981-2000 November	20	28	0.4423	ns			
1981-2010 September	30	21	**0.0055**	**Highly Significant**	**Decreasing**	**−2.1**	**−61.9**
1981-2010 November	30	28	**<0.0001**	**Very Highly Significant**	**Decreasing**	**−3.4**	**−101.2**
1991-2000 September	10	28	0.3117	ns			
1991-2000 November	10	36	0.1493	ns			
1991-2010 September	20	27	0.0264	Significant	Decreasing	−3.5	−69.1
1991-2010 November	20	36	**0.0002**	**Very Highly Significant**	**Decreasing**	**−4.9**	−98.9
2001-2010 September	*10*	*90*	*0.0197*	*Significant*	*Increasing*	*6.2*	*62.2*
2001-2010 November	10	94	0.9676	ns			

Note: In the Period column of this Rainfall Table, reference to ‘September’ and ‘November’ should be interpreted as ‘12 months prior to September’ and ‘12 months prior to November’ respectively.

3.5 Comparisons and relationships between depth medians and rainfall medians

In the paragraphs below we visually compare depth medians with rainfall medians (Sections 3.5.1 and 3.5.2)[1] and then more-closely examine some relationships (3.5.3 and 3.5.4). Depth regressions and rainfall regressions are compared in Section 3.6. Some paired t-Test depth comparisons are made in Section 3.7.

3.5.1 September depth and rainfall medians visually compared (Figure 9)

a) The 1981-1990 depth and rainfall series (both n=65) have well-matched peaks and troughs, with the marked exception of a pronounced peak in depths in 1983, despite there being no corresponding peak in annual rainfalls.

b) The 1981-2000 depth and rainfall series (both n=21) are quite well matched from 1981 to 1990, but again with the marked exception of a pronounced peak in depths in 1983, despite there being no corresponding peak in rainfalls. Also, there appears to be an upward trend in the depth data from 1981 to 1990, but not in the rainfall data. From 1991 to 1994 the series appear well matched, though note the small increase in depths but decrease in rainfalls in 1993. In 1995 depths decreased despite a sizeable increase in rainfalls. From 1995 to 1998 the series appear matched, but in 1999 there is only a small increase in depths despite a big increase in rainfalls. Viewed more broadly, the depths of 1995 to 2000 do not recover to the levels of 1992 and 1993, despite 1995 to 2000 appearing to be a period of normal to above normal rainfalls.

c) The 1981-2010 depth and rainfall series (both n=21) are identical to the 1981-2000 series over the period 1981 to 2000 as these series comprise the same wetlands and rainfall recording stations. In 2001 there is only a small decrease in depths despite a marked decrease in rainfalls. In 2002, depths decrease further despite a small increase in rainfalls (though note that the rainfalls in 2002 are still low by recent historical standards). From 2003 to 2010 the depth and rainfall series appear well-matched.

d) The 1991-2000 depth and rainfall series (both n=28) show much the same similarities and differences as in this period of the 1981-2000 and 1981-2010 series (described in (b) above).

e) The 1991-2010 depth and rainfall series (both n=27) show the same similarities and differences as in the corresponding periods of the 1981-2000 and 1981-2010 series (described in (b) and (c) above).

f) The 2001-2010 depth and rainfall series (both n=90) show a number of differences, only two of which are substantial, during the period 2001 to 2005. The depth and rainfall medians are both low in 2001, but whereas rainfalls increase markedly to 2002 there is a slight *decrease* in depths. In 2003 depths increase slightly whereas rainfalls decrease slightly. In 2004 depths decrease slightly whereas rainfalls increase and in 2005 there is a marked increase in depths despite only a small increase in rainfalls. From 2006 to 2010 the series are well-matched.

3.5.2 November depth and rainfall medians visually compared (Figure 10)

a) The 1981-1990 depth and rainfall series (both n=69) have well matched peaks and troughs, with the exception of 1982, where depths decrease while rainfalls increase, and 1983 where depths increase quite substantially despite a very small decrease in rainfalls.

b) The 1981-2000 depth and rainfall series (both n=28) are well matched from 1981-1990, except for the small increase in depths in 1990 despite a decrease in rainfalls. Also, the fall in median depths in 1987 is perhaps not quite as substantial as one might expect given the large decline in rainfall. From 1991 to 1993 the series appear well matched. In 1994 the fall in depths is again not as substantial as might be expected given the large decline in rainfalls. In 1995 there is only a slight increase in depths despite a large increase

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[1] The principal author found it useful to prepare Sections 3.5.1 & 3.5.2 as a way of forcing careful examination of the graphed data for patterns that could potentially guide future analyses. Readers, on the other hand, may wish to skip over this section.

in rainfalls. The peaks in rainfalls in 1996 and 1999 coincide with minor increases in depths. Viewed more broadly, the depths of 1995 to 2000 do not ‘recover’ to the levels of 1991 to 1993, despite 1995 to 2000 appearing to be a period of normal to above normal rainfalls.

c) The 1981-2010 depth and rainfall series (both n=28) are identical to the 1981-2000 series over the period 1981 to 2000 as these series comprise the same wetlands and rainfall recording stations. In 2001 there is a marked decrease in rainfalls accompanied by a decrease in depths. The increase in depths in 2002 is not as great as one might expect given the large increase in rainfalls. Similarly the large decrease in rainfall in 2006 coincides with a relatively small decrease in depths. In 2007 depths decrease while rainfalls increase. In other respects the series appear well matched over the period 2001 to 2010.

d) The 1991-2000 depth and rainfall series (both n=36) show much the same similarities and differences as in this period of the 1981-2000 and 1981-2010 series (described above in (b)). One additional point of difference is the relatively small increase in depths in 1992 compared with the large increase in rainfalls.

e) The 1991-2010 depth and rainfall series (both n=36) are identical to the 1991-2000 series over the period 1991 to 2000 as these series comprise the same wetlands and rainfall recording stations. From 2001 to 2010 the 1991-2010 series show very similar similarities and differences to those in the corresponding period of the 1981-2010 series (described above in (c)).

f) The 2001-2010 depth and rainfall series (n=94) are quite well matched, with only two noteworthy points of difference. Rainfalls increase in 2002, however there is no change in depths. In 2007, depths decline despite a slight increase in rainfalls.

3.5.3 Relationships between median depths and preceding 12 month rainfall medians

Relationships between depth medians and corresponding rainfall medians for two time series of wetlands (Sept 1981-2010, n=21 & Nov 1981-2010, n=28) are illustrated in Figures 11 & 12. Notable in Figure 11 (September) are the substantially higher (circled in blue) depth to rainfall ratios in 1983, 1988 to 1994 and 2001 and the particularly low (circled in yellow) ratios in 1981, 1999 and 2002 to 2004. Notable in Figure 12 (November) are the particularly high depth to rainfall ratios from 1988 to 1994 and particularly low ratios in 1999, 2002 to 2005, 2007 and 2010.

In Figure 13 (Sept) and Figure 14 (Nov) we indicate all years of higher (blue highlighting) or lower (yellow highlighting) than ‘average’ (i.e. regression line) depth to rainfall ratios and, in particular (additional highlighting), the years when the ratios were *substantially* above or below average as per the paragraph above. Three distinct periods become apparent. From 1981 to 1987, depth to rainfall ratios mostly departed little from ‘average’ (for this set of wetlands over this time period). From 1988 to 1994, ratios were consistently and substantially above average. From 1995/1996 to 2010, ratios were predominantly (13 of 16 years in Sept and 14 of 15 years in Nov) below average and, in several years, most noticeably 2002 to 2004/2005, consistently and substantially so.

The reasons for the apparent ‘shifts’ in depth to rainfall ratios, initially in the late 1980s to higher ratios (and depths) and then in the mid 1990s to lower ratios (and depths) have not been ascertained but could perhaps be due to differences in rainfall timing, rainfall intensity, evaporation rates, depths in preceding years and groundwater levels. For example, annual (Jan-Dec) pan evaporation rates in south-western Australia (boundaries as defined by the Bureau of Meteorology) were markedly higher in the period 1994-1996 than in preceding years since at least 1975 and have trended upwards at the rate of 41.2mm per decade from 1975 to 2012 (see Appendix 92; material sourced from Climate Change pages of BoM website in 2013).

Graphs and regression analyses similar to those of Figures 11 & 12 were also prepared for six of the other ten time series (i.e. for Sept & Nov of 1981-1990, 1991-2010 and 2001-2010)[1], however these are not presented as they do not individually span the entire period of interest.

[1] Not for the Sept & Nov 1981-2000 and 1991-2000 series, as these would be near-identical (Sept 1991-2000) to identical to the corresponding periods of the longer 1981-2010 and 1991-2010 series respectively.

The R-squared ('goodness of fit') values[1] of the Sept (n=21) & Nov (n=28) 1981-2010 series are 0.3341 and 0.4954 respectively. For comparison, the R-squared values of the other six 'graphed but not presented' series are: Sept 1981-1990 (0.6367, n=65), Sept 1991-2010 (0.3803, n=27), Sept 2001-2010 (0.4125, n=90) and Nov 1981-1990 (0.5953, n=69), Nov 1991-2010 (0.452, n=36) and Nov 2001-2010 (0.744, n=94).

3.5.4 Relationships between directions of change in depth and rainfall medians

Another aspect of the relationship between depths and preceding 12 month rainfalls that is of interest is the extent to which the directions of year-to-year changes in both are correlated. This is revealed in simple form in Table 4.

It is evident from Table 4 that there is a high degree of correlation between directions of year-to-year changes in depths and those of annual rainfall. In 82% (43% + 39%) of cases the directions are the same, while in 11% of cases depth medians decreased despite increases in preceding 12 months rainfall and in 7% of cases depth medians increased despite decreases in rainfall. Clearly other factors such as intensity and timing of rainfall, evaporation rates, wetland water levels at the start of each year, wetland overflow (i.e. outflow due to overtopping), and groundwater levels at the start of each year, may also play a part in determining directions (and magnitudes) of change in wetland depths and the extent to which these correlate with year-to-year changes in rainfall.

There is some apparent disparity between the months, with fewer differences in direction of change in the November data than the September data. One possible explanation resides in the seasonal distribution of rainfall in south-western Australia, resulting in the '12 months prior to September' period capturing more of the previous year's winter-spring (June – November) 'wet season' rainfall than '12 months prior to November'. Previous year wet season rainfall typically has less influence on current year water levels than current year wet season rainfall due to the drying effect of the intervening summer-autumn dry season.

Table 4. Directions of year-to-year changes in September (S) and November (N) depth medians and preceding 12 month rainfall medians. Note that this Table is derived from all 12 time series, not just the two time series of 1981-2010 as in Section 3.5.3, and that there are varying amounts (decadal periods) of overlap between these series.

YTY changes in Depth medians	YTY changes in Rainfall medians	
	Decreases	Increases
Decreases	**80 (43%)** (S37, N43)	**21 (11%)** (S13, N8)
Increases	**14 (7%)** (S11, N3)	**73 (39%)** (S33, N40)

The years in which the directions of change in depth and rainfall medians differed are highlighted in Figures 15 & 16. No clear patterns are evident and there is also little similarity in the timing (years) of differing directions of change between the two Figures (Sept & Nov).

3.6 Comparisons between depth regressions and rainfall regressions

In Table 5 we compare the depth regressions of Section 3.2 (Table 2 and Figures 3 & 4) with the rainfall regressions of Section 3.4 (Table 3 and Figures 7 & 8). In this Table we can see that there is a positive relationship between the existence of statistically significant trends in depths and statistically significant trends in rainfalls.

[1] An R^2 value of 1 indicates the regression line perfectly fits the data.

Table 5. Trends in depths and rainfalls matrix. This Table presents the values of Tables 2 and 3 combined in matrix form. (n = number of wetlands and number of rainfall recording stations; n.s. = not significant, S = significant, HS = highly significant, VHS = very highly significant. Where significant trends exist, the rates of change in depth or rainfall are shown, in mm per year).

		Sept			**Nov**		
Period	**Years**	**n**	**Depth**	**Rain**	**n**	**Depth**	**Rain**
1981-1990	**10**	65	n.s.	n.s.	69	n.s.	n.s.
1981-2000	**20**	21	n.s.	n.s.	28	n.s.	n.s.
1981-2010	**30**	21	VHS (-14)	HS (-2.1)	28	HS -10	VHS (-3.4)
1991-2000	**10**	28	n.s.	n.s.	36	n.s.	n.s.
1991-2010	**20**	27	VHS (-31)	S (-3.5)	36	VHS (-27)	VHS (-4.9)
2001-2010	**10**	90	n.s.	*S (6.2)*	94	S (-22)	n.s.

Note: In this Table, reference to 'Sept' and 'Nov' in relation to rainfall should be interpreted as '12 months prior to September' and '12 months prior to November' respectively.

Table 6, which is derived from Table 5, provides an indication of the strength of the relationships between levels of statistical significance of trends in rainfalls and those of depths. From this Table it can be seen that 'not significant' trends in rainfalls coincide mainly with 'not significant' but also with 'significant' (i.e. lowest level of significance) trends in depths and that the reverse is also true. In addition, 'highly significant' and 'very highly significant' trends in rainfalls coincide only with 'highly significant' (1) and 'very highly significant' (2) trends in depths, and 'highly significant' and 'very highly significant' trends in depths coincide with 'very highly significant' (2), 'highly significant' (1) and 'significant' (1) trends in rainfalls.

Table 6. Relationship between levels of significance of trends in rainfalls and those of depths.

	Rainfall Trends			
Depth Trends	**Not Significant**	**Significant**	**Highly Significant**	**Very Highly significant**
Not Significant	6	*1 (increasing)*		
Significant	1 (decreasing)			
Highly Significant				1 (decreasing)
Very Highly Significant		1 (decreasing)	1 (decreasing)	1 (decreasing)

Figure 17, which is also derived from Table 5[1], shows the relationship between rates of change in depths and rates of change in rainfalls. Only the four periods (time series) in which statistically-significant trends in both depths and rainfalls exist are shown. Note that both the x and the y axis values are negative. Noteworthy are the higher rates of change (decreases) in both rainfalls and depths in 1991-2010 compared with 1981-2010 and, in particular, *the much higher rates of change in wetland depths compared with rates of change in corresponding rainfalls in all four series*. The latter point is further demonstrated in Tables 7 & 8.

Table 7. Rates of change in wetland depths compared with rates of change in rainfalls: 1981-2010.

Period	**Rates of Change in Rainfalls (mm/yr)**	**Rates of Change in Depths (mm/yr)**	**Ratio (Depths / Rainfalls)**
Sep 1981-2010 (n=21)	−2.06 HS	−14.0 VHS	6.8
Nov 1981-2010 (n=28)	−3.37 VHS	−10.3 HS	3.1

(n = number of wetlands and number of rainfall recording stations; S = significant, HS = highly significant, VHS = very highly significant).

In Tables 7 & 8 we can see that in the four instances (time series) where both depth and rainfall trends are statistically significant, the rates of change in depths are 3.1 times (November depths 1981-2010) to 8.9 times (September depths 1991-2010) higher than the corresponding rates of change in ‘12 months prior to November’ and ‘12 months prior to September’ rainfalls.

Table 8. Rates of change in wetland depths compared with rates of change in rainfalls: 1991-2010.

Period	**Rates of Change in Rainfalls (mm/yr)**	**Rates of Change in Depths (mm/yr)**	**Ratio (Depths / Rainfalls)**
Sep 1991-2010 (n=27)	−3.45 S	−30.8 VHS	8.9
Nov 1991-2010 (n=36)	−4.95 VHS	−27.0 VHS	5.5

(n = number of wetlands & number of rainfall recording stations; S = significant, HS = highly significant, VHS = very highly significant).

It is also noticeable that the rates of change in ‘12 months prior to November’ rainfalls are substantially greater (by 1.31-1.50 mm/yr or 64%–43%) than the rates of change in ‘12 months prior to September’ rainfalls over the same time periods (years). On the other hand, rates of change in November depths are somewhat less (by 3.7–3.8mm/yr or 26%–12%) than rates of change in September depths over the same time periods. These differences, which have not been tested for statistical significance, are perhaps due mainly to differences between September and November sample sizes and compositions (compare the Sept & Nov ‘n’ values in Tables 7 & 8 and the compositions in Appendix 67), rather (especially in rainfalls) than being indicative of real seasonal differences in rates of change. The lower rates of change in November depths could also, however, be partly due to drying. Due to the seasonal timing of rainfall and evaporation in south-western Australia, wetlands in this region are more likely to be dry in November than September. Wetlands that are dry in one year cannot have lower surface water levels in subsequent years, even if rainfalls are lower in the subsequent year(s). These factors (dry wetlands and low rainfalls) combined may be sufficient to contribute significantly to the observed differences in rates.

[1] But with all values plotted to three decimal places, as in Appendix 70, rather than to zero or one decimal place as in Table 5.

The differences between the September and November *ratios* (depths / rainfalls) of Tables 7 & 8 are perhaps due to a combination of the differences in sample sizes and compositions *and* the statistical effect of drying referred to above. Statistical comparisons between September and November rates of change could be made using identical samples (e.g. sub-samples of the Tables 7 & 8 data), however this has not been attempted at this stage.

3.7 Paired t-Test (and Sign Test) comparisons between 1981-1990 and 2001-2010 depths

Many more wetlands were monitored in all Septembers (n=65) and all Novembers (n=69) of 1981-1990 and all Septembers (n=90) and all Novembers (n=94) of 2001-2010 than were monitored in all Septembers or all Novembers of 1981-2000, 1981-2010, 1991-2000 and 1991-2010 (n=21 to n=36, see Table 1)[1]. Not only is this the case, but the numbers of wetlands *common to* either all Septembers or all Novembers of both periods (1981-1990 and 2001-2010) are larger than the number of wetlands in each of those individual time series (1981-2000, etc.). Thus, 52 wetlands were monitored in all 20 Septembers of 1981-1990 and 2001-2010 and 52 wetlands[2] were monitored in all 20 Novembers of the same two decades. These two relatively large sets (52 in each) provide an opportunity to apply an additional statistical test — the paired t-Test — for differences in wetland depths from the first decade (1981-1990) to the last decade (2001-2010) of the 30 year period of interest.

The tests were performed using SAS Version 9.3, executing on the W32_SRV08 platform and residing on KENS-APP-063. Descriptive statistics generated by SAS showed that the raw depth data were not normally distributed and therefore not in a suitable form for parametric testing. The data were therefore transformed to the square root of depth (‘sqrtdepth’) in order to normalise their distribution[3]. The mean Sept 1981-90, Sept 2001-10, Nov 1981-90 and Nov 2001-10 square roots of depths of each wetland were then calculated. The parametric ‘paired t-Test’ was then used to test for significant differences between the 1981-90 and 2001-10 means. The null hypothesis was that the differences between the means of square roots of depths were zero. The ‘p’ values resulting from the paired t-tests were <0.0001, indicating that, collectively, the September 1981-90 means of square roots of depths were ‘very highly significantly’ different from the September 2001-10 means of square roots of depths (Table 9 and Appendix 49; see also Appendix 51). The corresponding transformed November data also produced ‘very highly significant’ results (Table 9 and Appendix 50; see also Appendix 52). On this basis it is concluded that the means of the untransformed data are also significantly different.

Table 9. Paired t-Test comparisons between 1981-1990 and 2001-2010 square roots of depths.

Month (number of wetlands)	1981-90 Mean of Means of Square Roots	2001-10 Mean of Means of Square Roots	Difference between Means of Means of Square Roots	‘p' value for Difference between Means of Square Roots	Significance of Difference between Means of Square Roots
September (52)	0.9610	0.7855	0.1754	<0.0001	Very Highly Significant
November (52)	0.9131	0.7420	0.1711	<0.0001	Very Highly Significant

Note that the Sept and Nov sets of wetlands are not identical; only 45 wetlands are common to both sets. Maps of their locations are in Appendices 65 & 66.

[1] This is because monitoring was discontinued at many wetlands in the early 1990s, but resumed at some and commenced at others later in the same decade (see Section 2.1).

[2] Not the same 52, only 45 are common to both of these sets (see Appendix 67).

[3] Square rooting of the raw depth data from each wetland transformed the Sep 1981-90, Sep 2001-10, Nov 1981-90 and Nov 2001-10 depth means from 1.14m, 0.85m, 1.11m, 0.84m to 0.96, 0.79, 0.91, 0.74 respectively, depth medians from 0.91m, 0.65m, 0.83m, 0.65m to 0.88, 0.75, 0.88, 0.74 respectively, skewness from 1.85, 2.25, 1.61, 1.96 to 0.67, 0.84, 0.28, 0.69 respectively, kurtosis from 4.88, 6.13, 3.48, 4.29 to 0.88, 0.93, 0.38, 0.24 respectively and the ‘p’ values of tests for normality from all <0.01 to mostly >0.05. The means, standard deviations and variances of the depth data prior to transformation were Sep 1981-90: 1.14, 0.82, 0.66; Sep 2001-10: 0.85, 0.84, 0.71; Nov 1981-90: 1.11, 0.83, 0.69; Nov 2001-10: 0.84, 0.87, 0.76.

The September and November 2001-2010 mean depths were 0.29m (25%) and 0.26m (23%) lower respectively than the corresponding 1981-1990 mean depths (Table 10).

Forty-two wetlands decreased in mean September depths from 1981-1990 to 2001-2010 and 10 increased (eight only marginally). The largest decrease in September depth means was Dumbleyung (2.41m to 0.86m) and the two large increases were Warden (1.22m to 2.26m) and Towerrinning (2.65m to 3.04m) (Appendix 51).

Thirty-nine wetlands decreased in mean November depths from 1981-1990 to 2001-2010 and 13 increased (11 only marginally). As in Septembers, the largest decrease in depth means was Dumbleyung (2.30m to 0.73m) and the two large increases were Warden (1.11m to 2.24m) and Towerrinning (2.54m to 2.93m) (Appendix 52).

The locations of the two sets of 52 wetlands referred to in this section are shown in Appendices 65 & 66.

Table 10. Comparisons between 1981-1990 and 2001-2010 mean depths.

Month (number of wetlands)	1981-90 Mean (Median) of Means of Depths	2001-10 Mean (Median) of Means of Depths	Change in Mean (Median) of Means of Depths	% Change in Mean (Median) of Means of Depths
September (52)	1.14m (0.91m)	0.85m (0.65m)	–0.29m (–0.26m)	–25% (–29%)
November (52)	1.11m (0.83m)	0.84m (0.65m)	–0.26m (–0.18m)	–23% (–22%)

Note that the September and November sets of wetlands are not identical; only 45 wetlands are common to both sets.

An alternative approach to testing for difference between depths in 1981-1990 and those of 2001-2010 is to use the non-parametric ‘Sign Test’, which tests for a difference between medians rather than means (in this case the medians of the means rather than the means of the means). The Sign Test is considered more powerful (Pappas & DePuy 2004) than the similar ‘Ranked Sign Test’ if the data are obtained from a ‘heavy-tailed’ distribution or contain outliers, as is the case with the mean depth data. The Sign Test was performed separately on the September and November mean depth data and the results indicated that the medians of the mean 1981-1990 and mean 2001-2010 depths of the 52 individual wetlands were very highly significantly different (Sept $p<0.0001$; Nov $p=0.004$), thus corroborating the results of the paired t-Tests above.

3.8 Inclusion of 1980 depths

In the late stages of preparing this report, the principal author re-discovered some graphical material, first prepared in 1991, in which September and November wetland depths (and salinities) were compared annually from 19<u>80</u> to 1991. This material is reproduced in Appendix 97[1] and in Appendix 98 is compared, by juxtaposition, with the depth data of Figures 1 & 2 combined. Two features are notable. Firstly the strong similarity in appearance between the two graphs (Appendix 98) over the period in common (1981-1991), this despite some differences in wetland numbers and compositions (see text of Appendix 98 for explanation). Secondly the very low median depths (and 60th & 40th percentiles) in 1980. Superficially at least, these are comparable with the lowest of the period 1981-2010, i.e. with 1987 and 2010.

Because of the potential for the very low depth values of 1980 to significantly ‘alter’ the results of the 30 year (1981-2010) trends analyses, it was decided that the regression analyses (Section 3.2) of the 1981-2010 September and November depth data should be re-run with the 1980 data added (they were not included initially because they fell

[1] See also Appendix 95, in which cumulative percentages of September and November wetland depths are compared annually from 1980 to 1989.

outside the first arbitrary decadal period, which commenced in 1981)[1]. Of the ≈ 59 wetlands monitored in 1980, only 17 (September) and 26 (November) were in the 1981-2010 series, so only these were used in the 1980-2010 're'-analyses. The results of these re-analyses indicated that there was a significant trend (downwards; $p<0.05$) in September depths over the 31 year period of 1980-2010, however there was no significant trend ($p=0.069$) in November depths over the same period (Appendix 70). These results are different from the 1981-2010 results (which were based on slightly larger samples of wetlands), where the downward trend in September depths was very highly significant ($p=0.0001$) and November depths also trended downwards with a high level of significance ($p=0.0017$) (Table 2). This further emphasizes the point that choice of start and finish years can significantly affect the results of trend analyses, in this case because median depths were much lower in 1980 than in 1981.

Note that 1980 (in this case Jan-Dec, not Sept-Aug or Nov-Oct as elsewhere in this report) was the fifth year in succession of rainfalls (annual District Averages) in all five Meteorological Districts[2] of the south-west being below their long term averages, a situation unprecedented since at least 1901 (the earliest year of District Averages) and not replicated to at least 2012[3]. Depth analyses based on start (or finish) years so atypical of long term conditions must be considered as special cases.

4. SOME ADDITIONAL CONSIDERATIONS

In future analyses (i.e. in future reports) the following issues will warrant consideration as they have important implications for the types of statistical techniques that will be appropriate, for the selection of wetlands for inclusion in the analyses, and for the categorisation of wetlands within the analyses, depending upon the questions being asked.

4.1 Cumulative effects of rainfall

In this report we have not examined by specific statistical analysis the cumulative effects of consecutive years of higher-than-average or, more commonly in recent decades, lower-than-average annual rainfalls on wetland depths.

At an individual wetland level, we know that single or consecutive high rainfall events or periods of well-above-average rainfalls may increase the water levels of some wetlands to exceptional heights and that several years may be required for these to decline through evaporation to more normal levels. Dumbleyung Lake, for example (Figure 18) increased in depth by more than 2.0m following post-cyclonic rains (ex-Tropical Cyclone Bruno) in January 1982 (Appendix 85)[4] and by 3.5m following heavy winter rains in 1983[5]. Four years of evaporation were then required for this lake's water level to decline to what is now considered 'normal' (≈0.5m; Lane *et al.* 2015)[6].

Other SWWMP wetlands that have displayed similar responses to above average rainfalls during the past three or more decades to those of Dumbleyung include Anderson, Atkins Yate, Bennetts, Coomalbidgup, Coyrecup, Hinds, Jerdacuttup, Kent 29020, Kwornicup, Little White, Logue, Martinup, Mettler, Parkeyerring, Pillenorup, Ronnerup, Taarblin, White (Narrogin), Yaalup and Yellilup (Lane *et al.* 2004, 2015).

Consecutive years of *low* rainfalls also have cumulative effects on the water levels of some wetlands, causing them to decline in the second and any subsequent years of drought to (in some cases) previously unrecorded levels. Spectacular examples of wetlands that suffered such declines in the mid-1980s but subsequently recovered due to returns to

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[1] Other SWWMP data, from 1978 and 1979, also fell outside this period. Some of it (Nov data only, plus the Nov 1980 data) is presented in Appendix 94 and could perhaps be used (particularly the larger 1979 and 1980 sets) in future reports.

[2] See the Bureau of Meteorology website http://www.bom.gov.au/climate/cdo/about/rain-districts.shtml for the boundaries of these Districts.

[3] See Appendix 96 for a graph of the 1913-1990 District Average rainfall data. The 1901-1912 and 1991-2012 data referred to in this sentence, but not shown in Appendix 96, were accessed separately from the Bureau of Meteorology website in August 2013.

[4] See Appendix 86 for a similar, though less intense, rainfall event in January 1990.

[5] See the two month interval Dumbleyung depths on p.64 of Jaensch *et al.* (1988).

[6] As an aside, Dumbleyung also demonstrates (Figure 18) that although single, high intensity rainfall events (e.g. ex-Tropical Cyclone Bruno) may greatly increase wetland depths within hours or days of occurring, they do not necessarily result in total annual rainfall in that year being much, or at all, above normal.

more normal rainfalls are Byenup (Figure 19), Poorginup and Tordit-Gurrup[1], all within the Muir-Unicup complex east of Manjimup (Lane *et al.* 2004). Other wetlands that have experienced similar declines in recent years but not yet recovered include Guraga and Logue (Lane *et al.* 2015).

Wetlands that are both shallow and perched, that is, wetlands that overflow at low water levels and are not well-connected to groundwaters, typically dry out in most years. Consecutive years of lower or higher than average rainfalls may have little or no cumulative effect on the water levels of these wetlands. Some wetlands that behave in this way are 'Boyup Brook 18239', Broadwater, Dulbinning and Station (Lane *et al.* 2015).

4.2 Depth limits

Potential *decreases* and the potential *rates of decrease* in the median depth of groups of wetlands are limited by the fact that when the surface water levels of wetlands reach zero, i.e. dryness, they cannot decrease further. This has significance for the analysis, interpretation and reporting of long term trends. If rainfalls in the south-west continue to decline as predicted (Hope *et al.* 2015), more wetlands will be dry by September and, in particular, November each year than in the past and the magnitude and rate of decline in median depths in subsequent years of groups containing one or more of these wetlands may, as a consequence, be reduced. In view of this, it may be undesirable to include some wetlands that dry (e.g. those that have dried in consecutive years) in some future analyses, for example when magnitudes or rates of decline in wetland depths are being further compared with magnitudes and rates of decline in rainfalls.

It is also important to note that potential *increases* and potential *rates of increase* in the median depth of groups of south-west wetlands are also limited, since most if not all have levels at which they are full and begin to overflow. Additional rains and inflow do not substantially increase the depths of these already-full wetlands, except during major floods when surrounding landscapes are flooded thereby increasing the depth of water temporarily retained (by surrounding floodwaters) in the wetlands. Minor increases in the depths of already-full wetlands may occur temporarily during minor floods, when the rates of increases in water volume exceed the outflow capacities and water 'backs up' in the wetlands. If the overflow levels of all or a sizeable sample of SWWMP wetlands were known[2], these wetlands could be categorised according to their potential maximum depths and this attribute could be taken into account in any future analyses of long term rainfall and depth trends where potential maximum depth is a significant consideration.

4.3 Stable or erratic depths

The water levels of a few SWWMP wetlands such as Bambun, Chandala, Moates and Wilson are relatively little-affected by variations in annual rainfall, perhaps due to strong connections to persistent groundwaters and/or high runoff volume (e.g. due to large catchment area) to storage volume ratios. Note that the long term average September and November depths of the four exampled wetlands range widely, from ≈ 0.9m (Chandala) to ≈ 4.3m (Moates) (Lane *et al.* 2015).

A few SWWMP wetlands are dry or near dry (<0.2m) in almost all years, with substantially higher water levels being recorded only after exceptional rains, once each decade or two, e.g. Ronnerup (2.2m in 2000), Varley (0.9m in 2000), 'White (Narrogin)' (2.2m in 1983) and Yarra Yarra (1.0m in 1999) (Lane *et al.* 2015).

4.4 Management interventions, shallowing and deepening

On-ground management interventions may affect the water levels of individual south-west wetlands, for example by diverting surface water flows into wetlands (e.g. Crackers Swamp, Thomsons Lake, Lake Towerrinning) or away from wetlands (e.g. Toolibin Lake) or perhaps both (Lake Powell?) or by manipulating outflow levels (e.g. Beverley Lakes, Lake Towerrinning) or 'topping up' with pumped water (e.g. Lake Jandabup) (Lane 1994; Lane *et al.* 2004, 2015). Such wetlands might need to be excluded from some future trends analyses, depending upon the questions being asked.

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[1] Though note that Tordit-Gurrup is currently experiencing a record decline in water level — and decline in pH and rise in salinity — from which it has yet to recover (Lane *et al.* 2015).

[2] Some are known, as a result of bathymetric surveys and other work undertaken by DEC (formerly CALM, now DPaW) and others, particularly since 1998 (see Section 3 and Table 6 of Lane *et al.* 2015).

Future analyses might also be complicated by the gradual infilling of some south-west wetlands by sedimentation or by peat formation or loss, e.g. loss due to fire. Several SWWMP wetlands in the Esperance district may have shallowed significantly in recent years (based on J. Lizamore, pers. comm., 15/02/2013) presumably due to increased sedimentation rates as a consequence of increased catchment flows and erosion. On the other hand, dry wetlands may lose sediments through wind action (saltation, ablation) and this loss may increase if wetlands dry more-frequently or for longer periods.

Rates of sedimentation or erosion and peat formation or loss are not currently measured under SWWMP, except in the most minor of ways (occasional recording of lake bed levels at fully exposed depth gauges). More-substantial 'baselines' have been established at some wetlands (those that have been bathymetrically mapped, see Table 6 in Lane *et al*. 2015), however this is an expensive process, unlikely to be repeated at individual wetlands more than once or twice (if the past is a guide) each century. In any case, bathymetric mapping alone is only likely to reveal large changes (>0.1m) in lake floor elevations due to the inherent limitations of the rapid survey equipment (Real-Time Kinematic Differential Global Positioning System or RTK DGPS) often used.

4.5 Evaporation

Annual (January-December) pan evaporation rates in 'Southwestern Australia'[1] during the period 1981 to 2010 ranged between 1636mm (1992) and 1945mm (1994) (from BoM bar chart in Appendix 92). This is a range of 309mm, or 19% of the 1992 amount. If wetland evaporation rates are similar, they are of sufficient magnitude to contribute significantly to year-to-year and longer term variations in wetland water levels.

Pan evaporation rates are not necessarily lower than usual in 'wetter than usual' years. Comparison of the BoM bar charts in Appendices 89 & 92 shows that in 1995, for example, the evaporation rate (1858mm) and annual rainfall (668mm) were both relatively high (for recent decades). Interestingly, 1995 is also a year when wetland median depths declined (September) or rose very little (November) despite marked increases in '12 months to September' and '12 months to November' rainfalls (Figures 9 & 10; see also Appendix 84 for monthly rainfall distributions from Nov 1994 to Nov 1995). While this single and selective observation is clearly insufficient to establish cause and effect (in this case whether higher evaporation rates 'negated' higher rainfalls), it does serve to illustrate why some consideration of evaporation rates will be important in developing an understanding of factors responsible for trends in wetland depths.

5. DISCUSSION

In this report we have attempted to determine whether long-term trends exist in the spring (September and November) water levels of south-western Australian wetlands over the 30 year period between 1981 and 2010 and, if so, the extent to which these correlate with trends in rainfalls.

Through visual comparisons and standard statistical analyses we have shown that water levels have generally trended downwards from 1981 to 2010 and, in particular, in the two decades since 1991. These declines in wetland water levels are strongly correlated with declines in rainfalls. The rates of change (mm/yr) in water levels are also *substantially greater than* the rates of change in rainfalls. With further declines in south-west rainfall predicted, these findings have significant implications for the future of south-west wetlands.

The trends in wetland water levels (and rainfalls) have not been uniform across the south-west. While the water levels of many wetlands have declined, some have not and a few have increased. This has implications for the long-term survival of south-west wetland biota and the prioritization of conservation efforts. Some elements of the biota may be more-affected by long-term changes in rainfall patterns and consequent changes in wetland hydrology than other elements, either because of their sensitivity to hydrological changes, or the types of wetlands they inhabit, or the peculiarities of their geographic distributions relative to spatial changes in rainfalls and water levels in the south-west.

[1] 'Southwestern Australia' as defined by the Commonwealth Bureau of Meteorology. See Appendix 87 for a map showing 'Southwest Western Australia' as defined by the Indian Ocean Climate Initiative (IOCI).

Further analyses of wetland water level, salinity, ionic composition, nutrient, pH and bathymetric data that has been obtained though SWWMP during the past 38 years, together with rainfall and possibly other related data (e.g. waterbird, macroinvertebrate, vegetation, water chemistry and shallow groundwater data obtained under the State Salinity Strategy by Halse, Pinder, Gibson, Lyons, Cale, Walker and others) will be needed for a comprehensive assessment and forecasting of likely futures for south-west wetlands and their biotic and other values. The current report will hopefully provide a sound and adequate basis for the design of such further analyses.

6. ACKNOWLEDGEMENTS

The authors wish to thank the many people who have been involved in and supported SWWMP since its inception. A comprehensive list of these contributors and their respective contributions is provided in the Acknowledgements section of Lane *et al.* (2015).

DPaW Wetlands Conservation Program Leader Adrian Pinder made many useful comments on a near-final draft of this report and this assistance is also appreciated.

The Commonwealth of Australia's Bureau of Meteorology is the source and copyright holder of the rainfall data and rainfall maps presented in this report. These data and maps are presented with permission of the Bureau.

7. REFERENCES[1]

Hope, P., Abbs, D., Bhend, J., Chiew, F., Church, J., Ekström, M., Kirono, D., Lenton, A., Lucas, C., McInnes, K., Moise, A., Monselesan, D., Mpelasoka, F., Timbal, B., Webb L. & Whetton, P. (2015). *Southern and South-Western Flatlands Cluster Report*, Climate Change in Australia Projections for Australia's Natural Resource Management Regions: Cluster Reports, eds. Ekström, M. *et al.*, CSIRO and Bureau of Meteorology, Australia.

Jaensch, R.P., Vervest, R.M. & Hewish, M.J. (1988). *Waterbirds in nature reserves of south-western Australia 1981-1985: Reserve accounts.* Royal Australasian Ornithologists Union Report 30. 290pp.

Lane, J.A.K., Clarke, A.G. & Winchcombe, Y.C. (2015). *South West Wetlands Monitoring Program Report 1977-2014.* Western Australian Department of Parks & Wildlife, Busselton. 181pp.

Lane, J.A.K., Pearson, G.B., Clarke, A.G., Winchcombe, Y.C. & Munro, D.R. (dec.) (2004). *Depths and salinities of wetlands in south-western Australia: 1977-2000.* Western Australian Department of Conservation & Land Management. 129pp.

Pappas & DePuy (2004). An overview of non-parametric tests in SAS©: when, why and how. Paper TU04. Duke Clinical Research Institute, Durham, North Carolina, USA. (http://analytics.ncsu.edu/sesug/2004/TU04-Pappas.pdf accessed 20Aug2013).

[1] For an extensive list of reports and publications relating to the Western Australian *Salinity Action Plan*, *State Salinity Strategy* and associated wetland survey and monitoring programs of which SWWMP is one, refer to Lane *et al.* (2015).

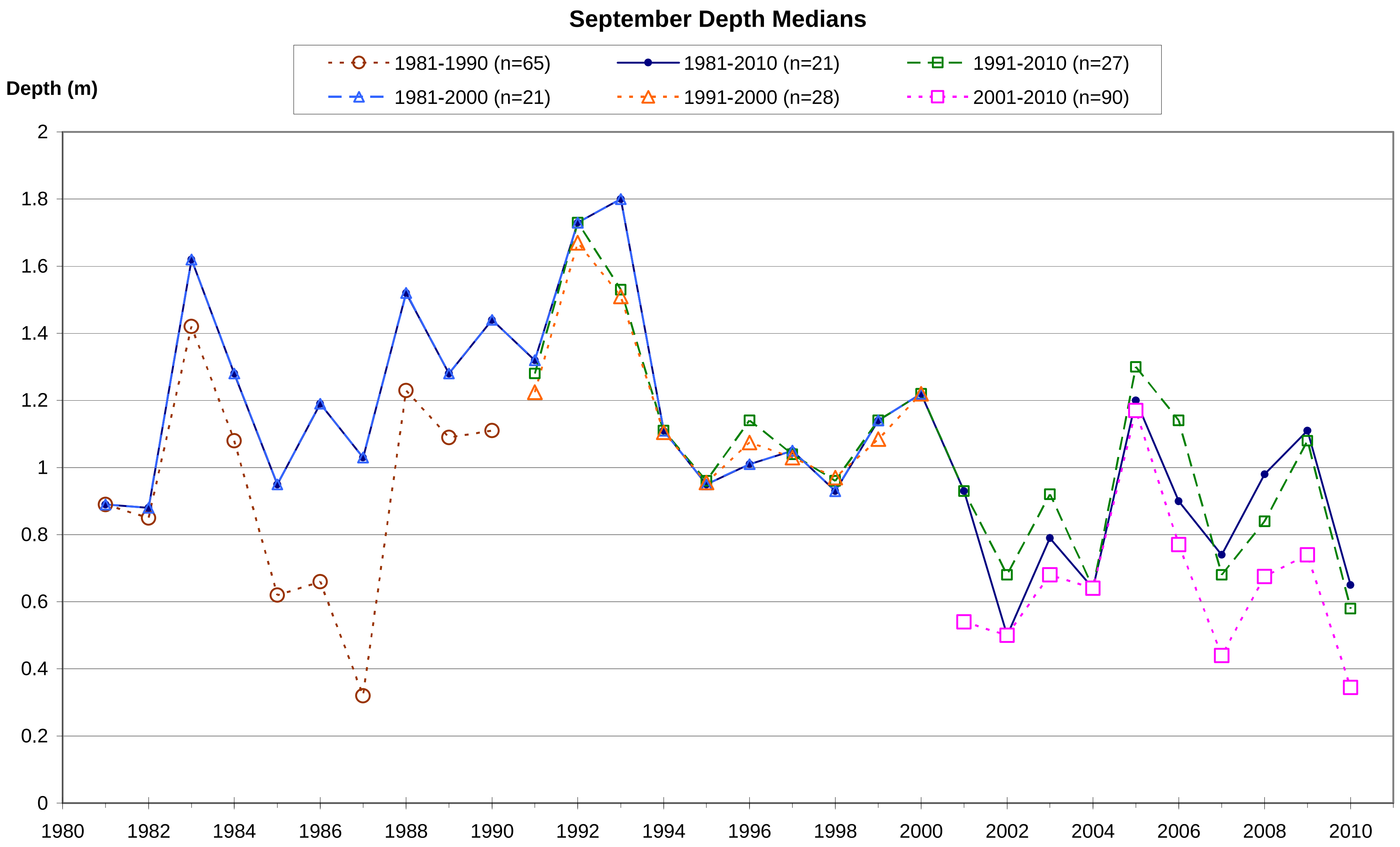


Figure 1. September depth medians between 1981 and 2010.

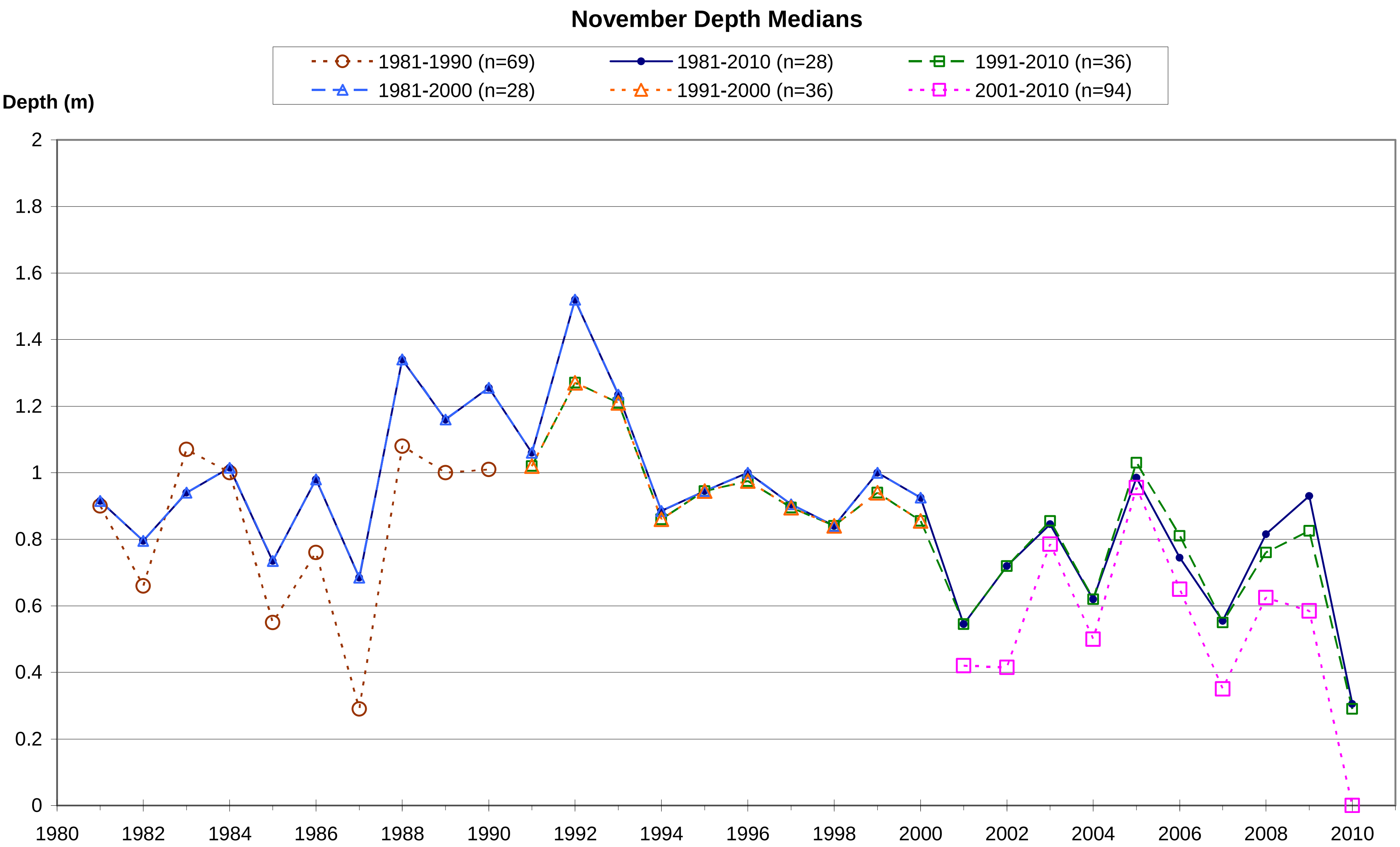


Figure 2. November depth medians between 1981 and 2010.

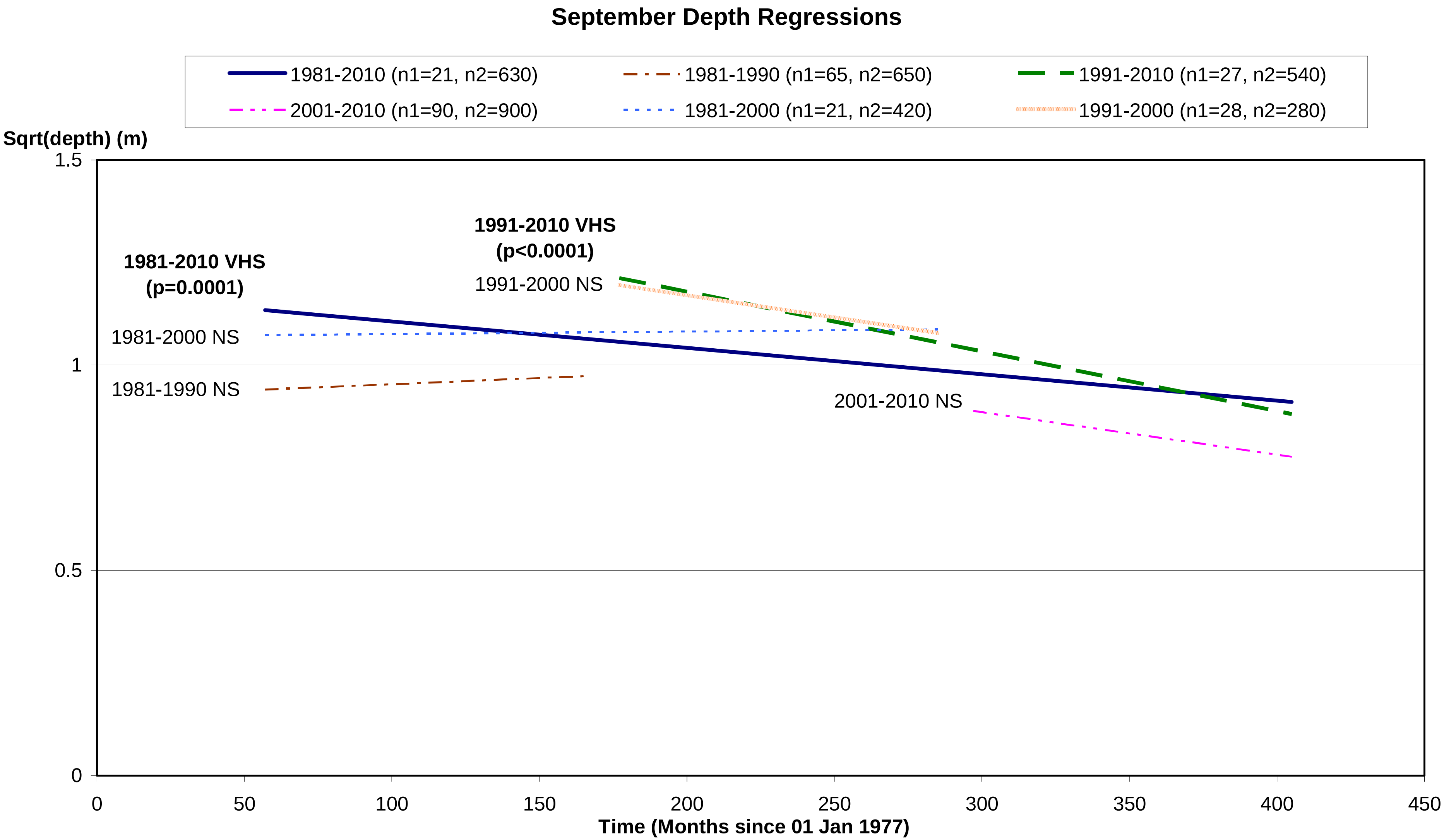


Figure 3. September depth regressions between 1981 and 2010.

n1 = number of wetlands, n2 = number of data points (n1 x number of years). See Appendices 25–30 for data points and equations.

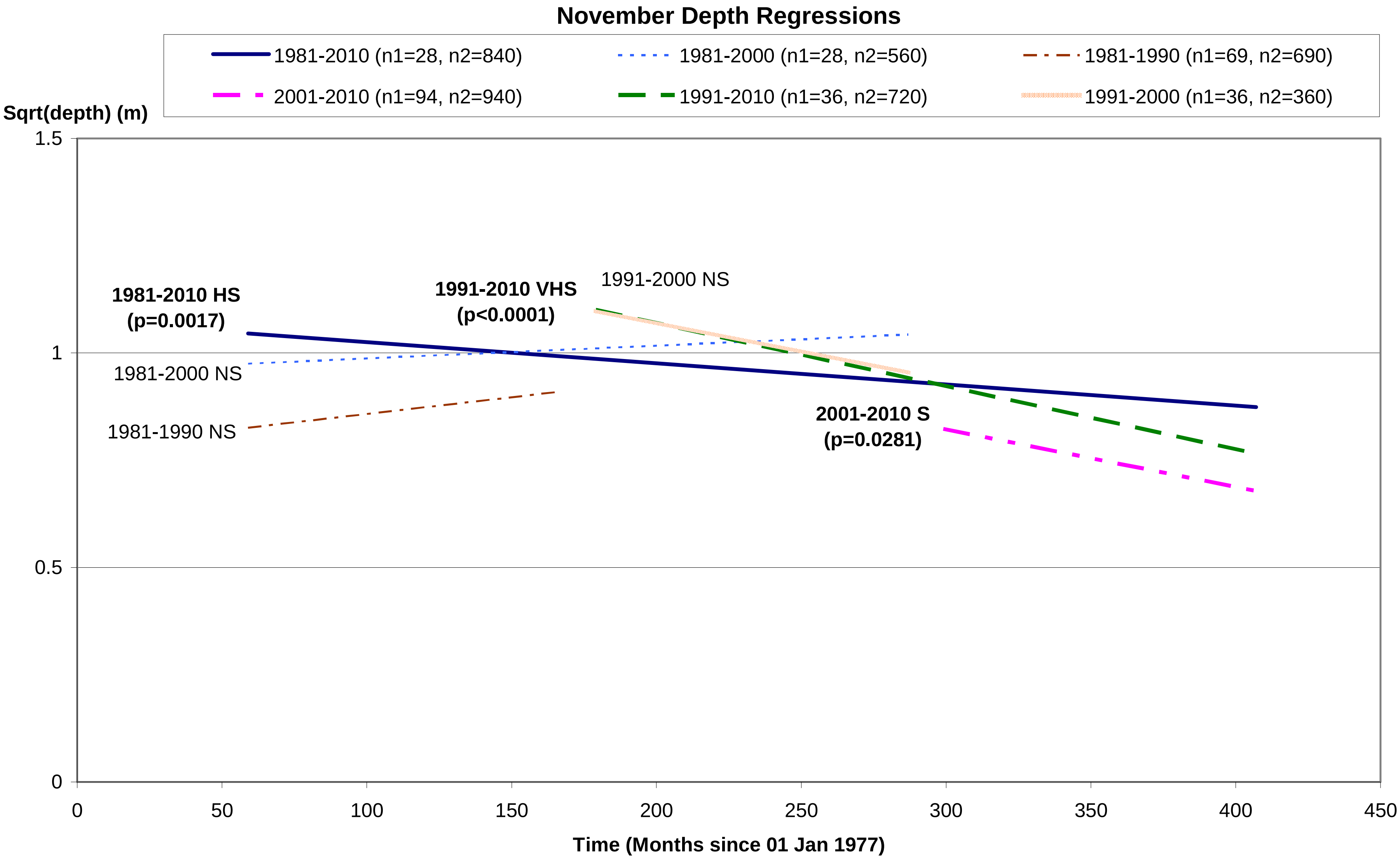


Figure 4. November depth regressions between 1981 and 2010.

n1 = number of wetlands, n2 = number of data points (n1 x number of years). See Appendices 31-36 for data points and equations.

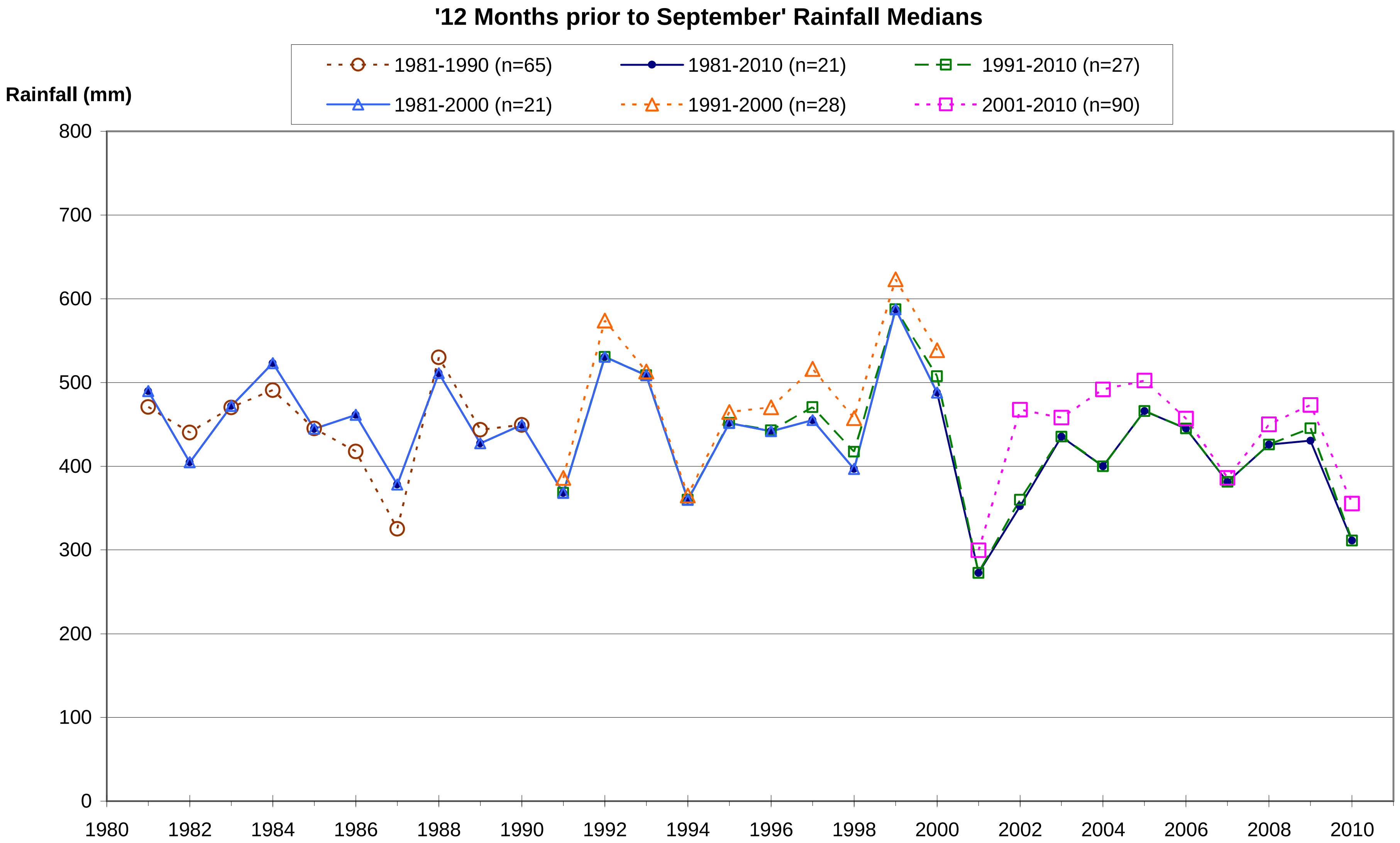


Figure 5. '12 months prior to September' rainfall medians between 1981 and 2010.

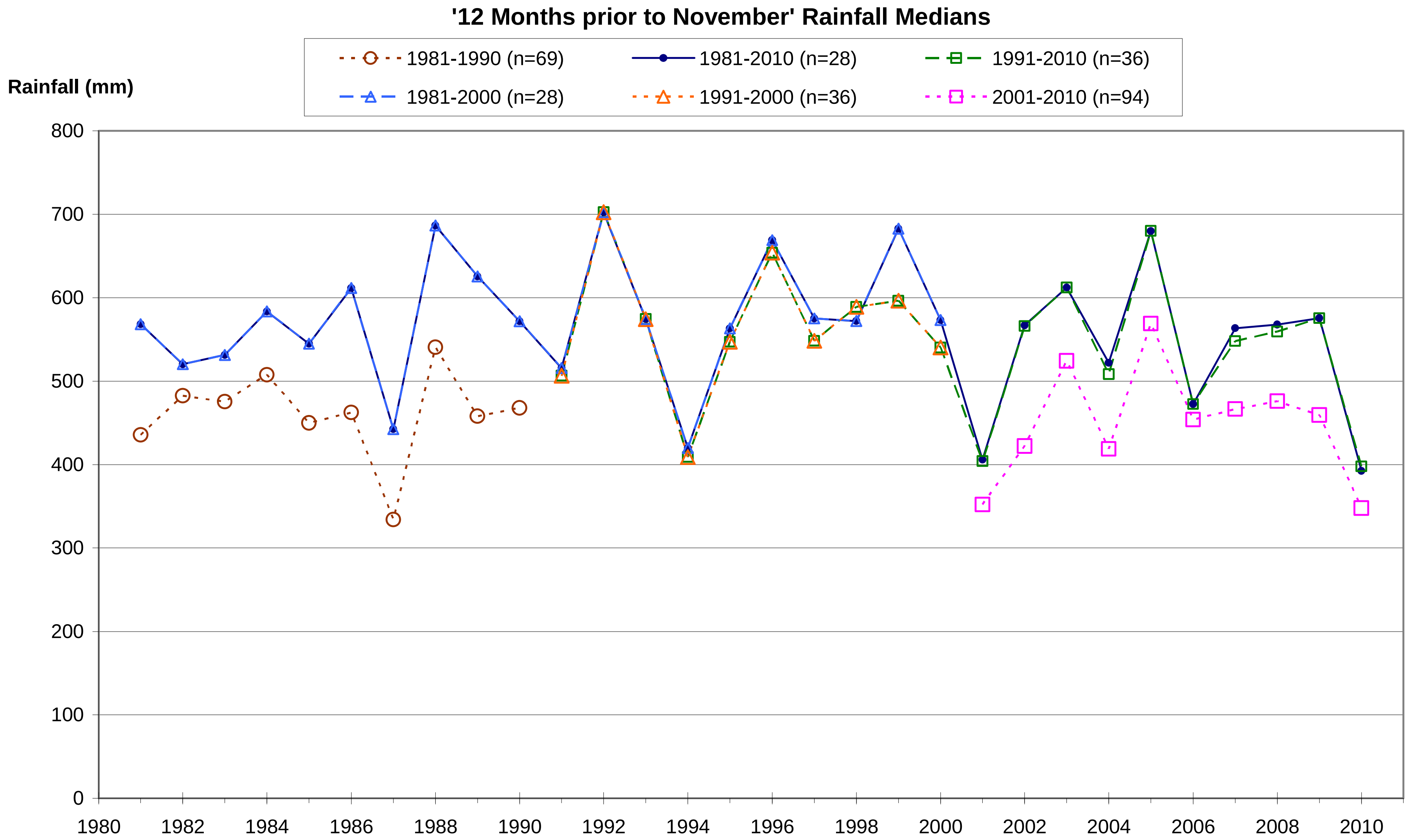


Figure 6. '12 months prior to November' rainfall medians between 1981 and 2010.

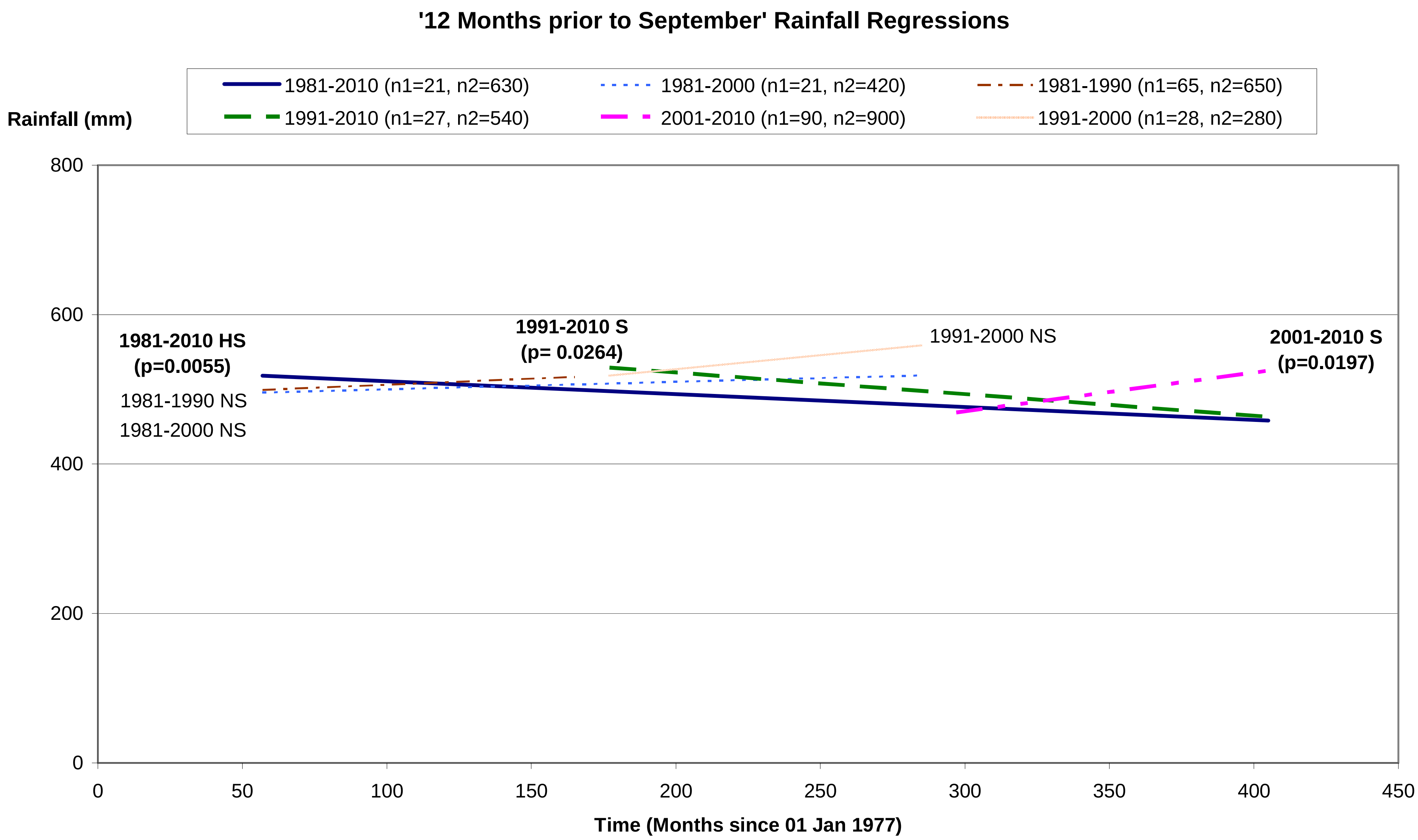


Figure 7. '12 months prior to September' rainfall regressions between 1981 and 2010.

n1 = number of wetlands, n2 = number of data points (n1 x number of years). See Appendices 37–42 for data points and equations.

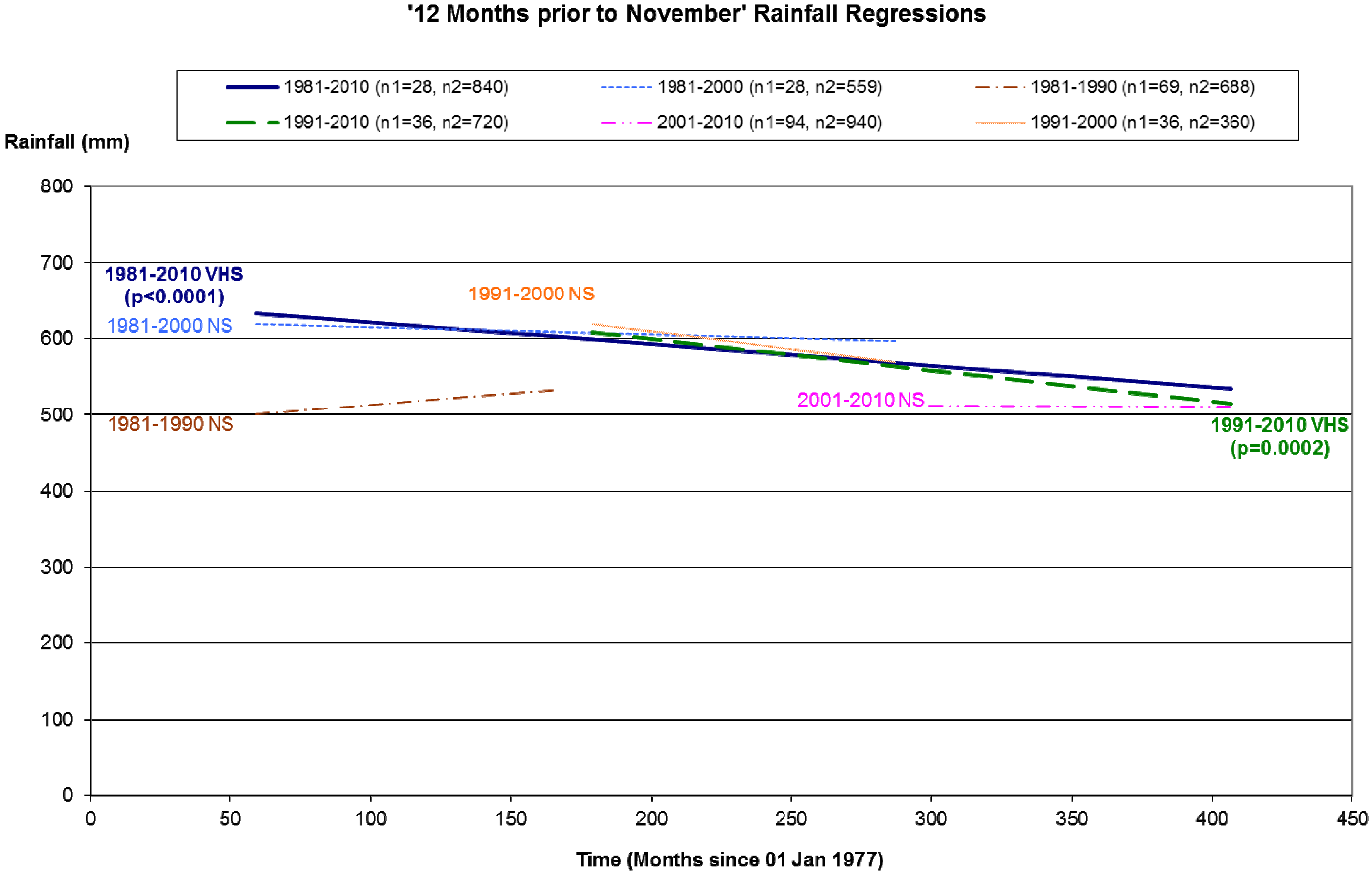


Figure 8. '12 months prior to November' rainfall regressions between 1981 and 2010.

n1 = number of wetlands, n2 = number of data points (n1 x number of years). See Appendices 43–48 for data points and equations.

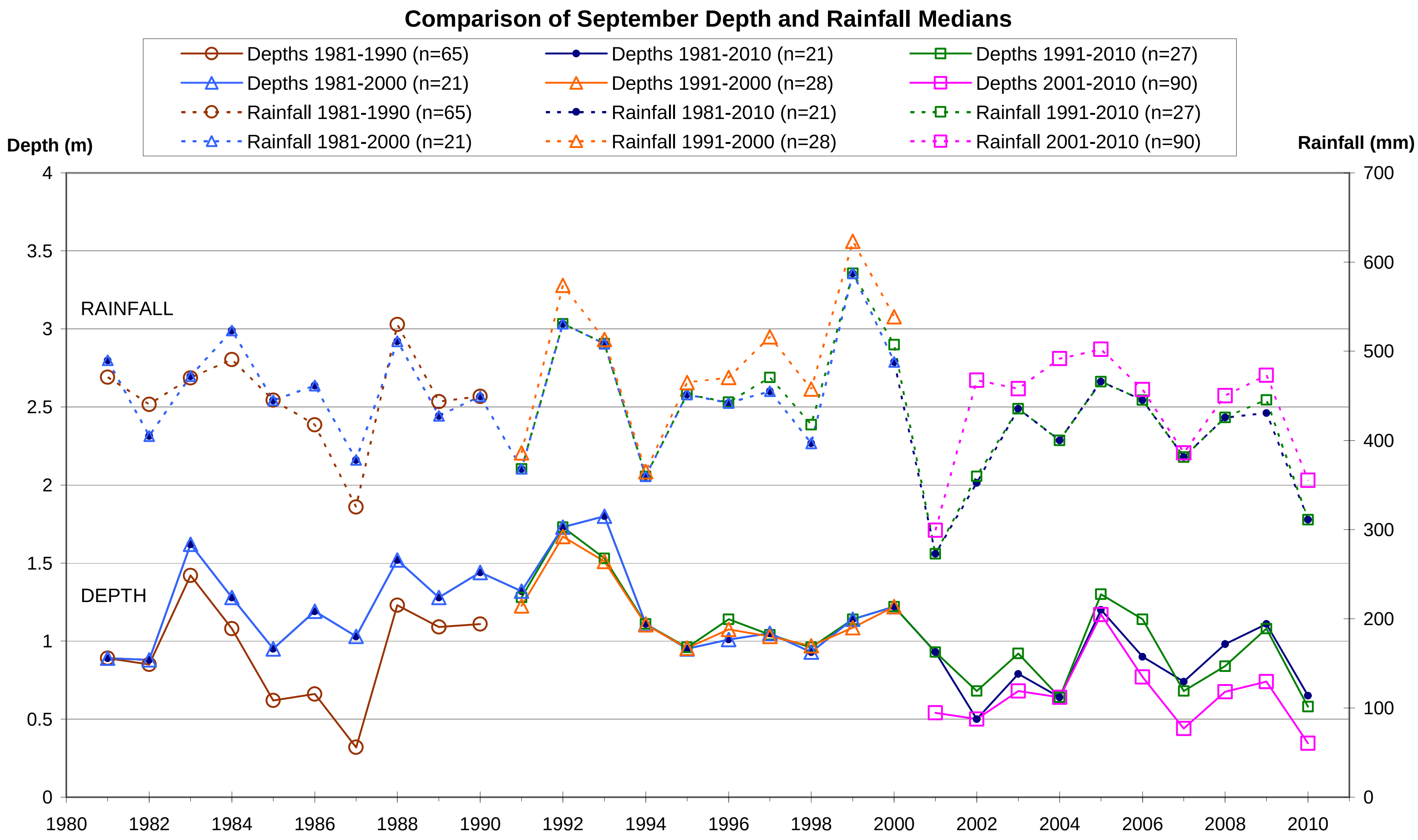


Figure 9. September depth medians and '12 months prior to September' rainfall medians between 1981 and 2010.

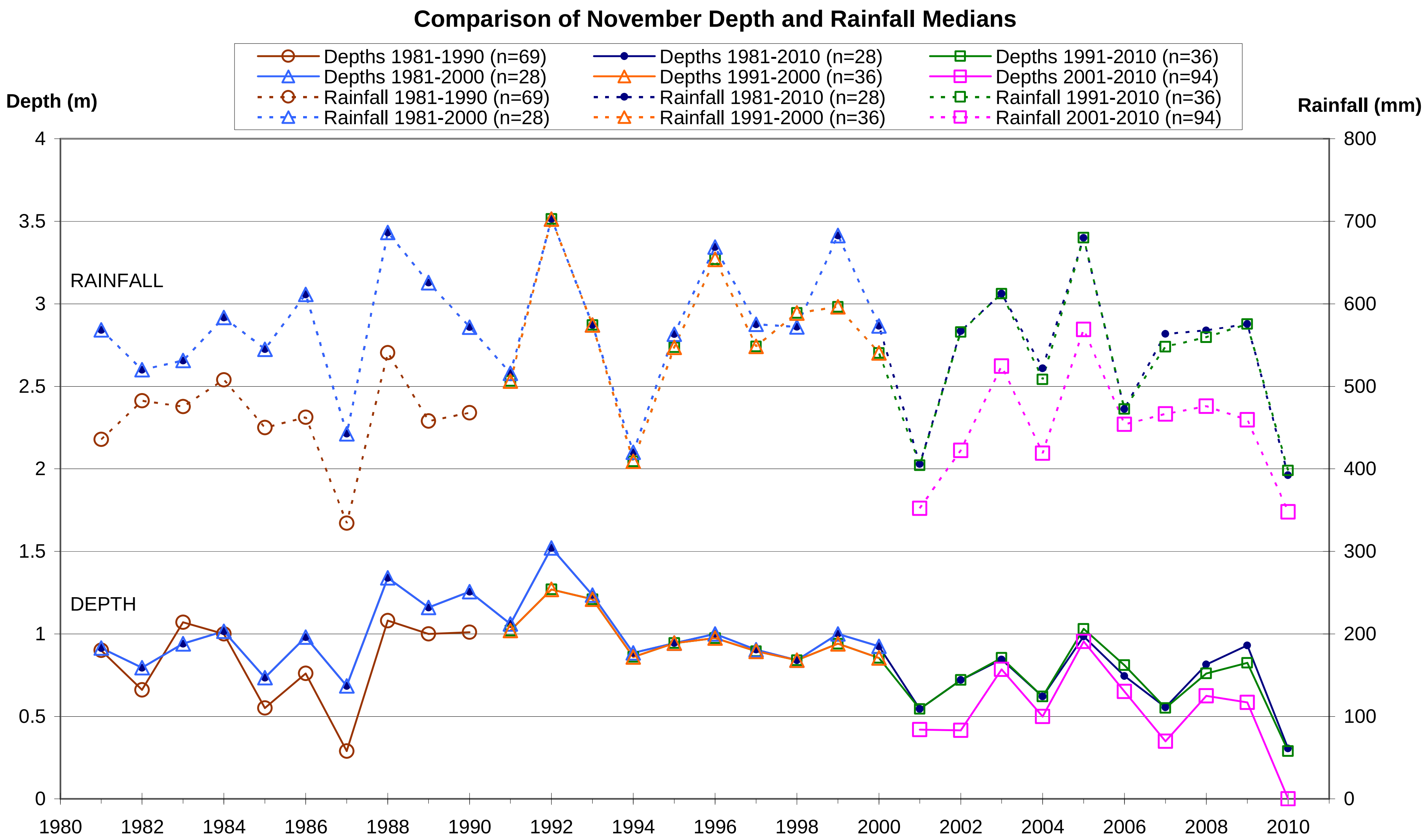


Figure 10. November depth medians and '12 months prior to November' rainfall medians between 1981 and 2010.

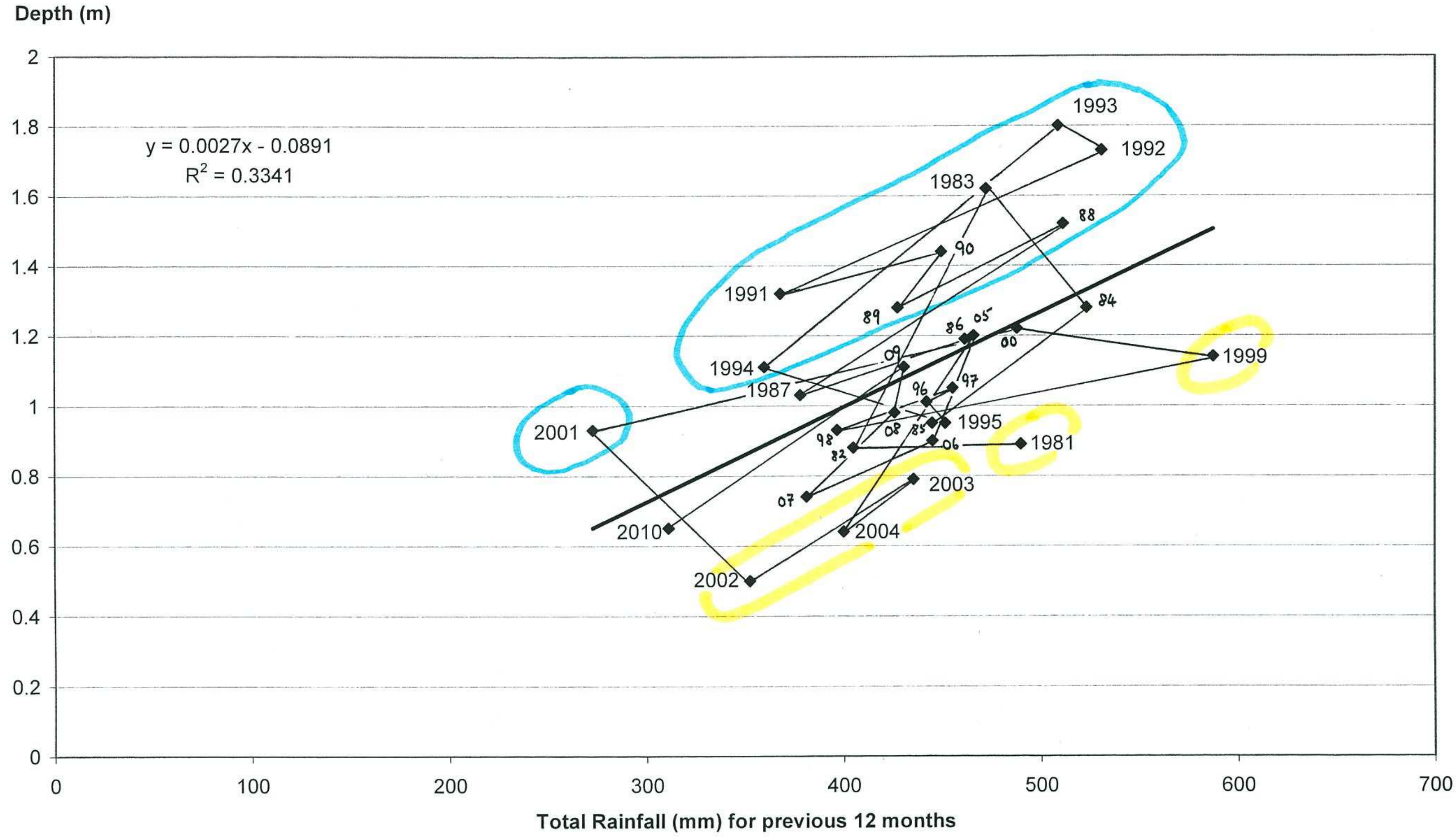


Figure 11. Regression of Sept depth medians versus corresponding '12 months prior to Sept' rainfall medians, 1981–2010 time series.

Circling with highlighter indicates Septembers with depth to rainfall ratios that are *substantially* higher (blue) or *substantially* lower (yellow) than 'average' (regression line). Connecting lines indicate chronological sequence. See Section 3.5.3 for further explanation and discussion.

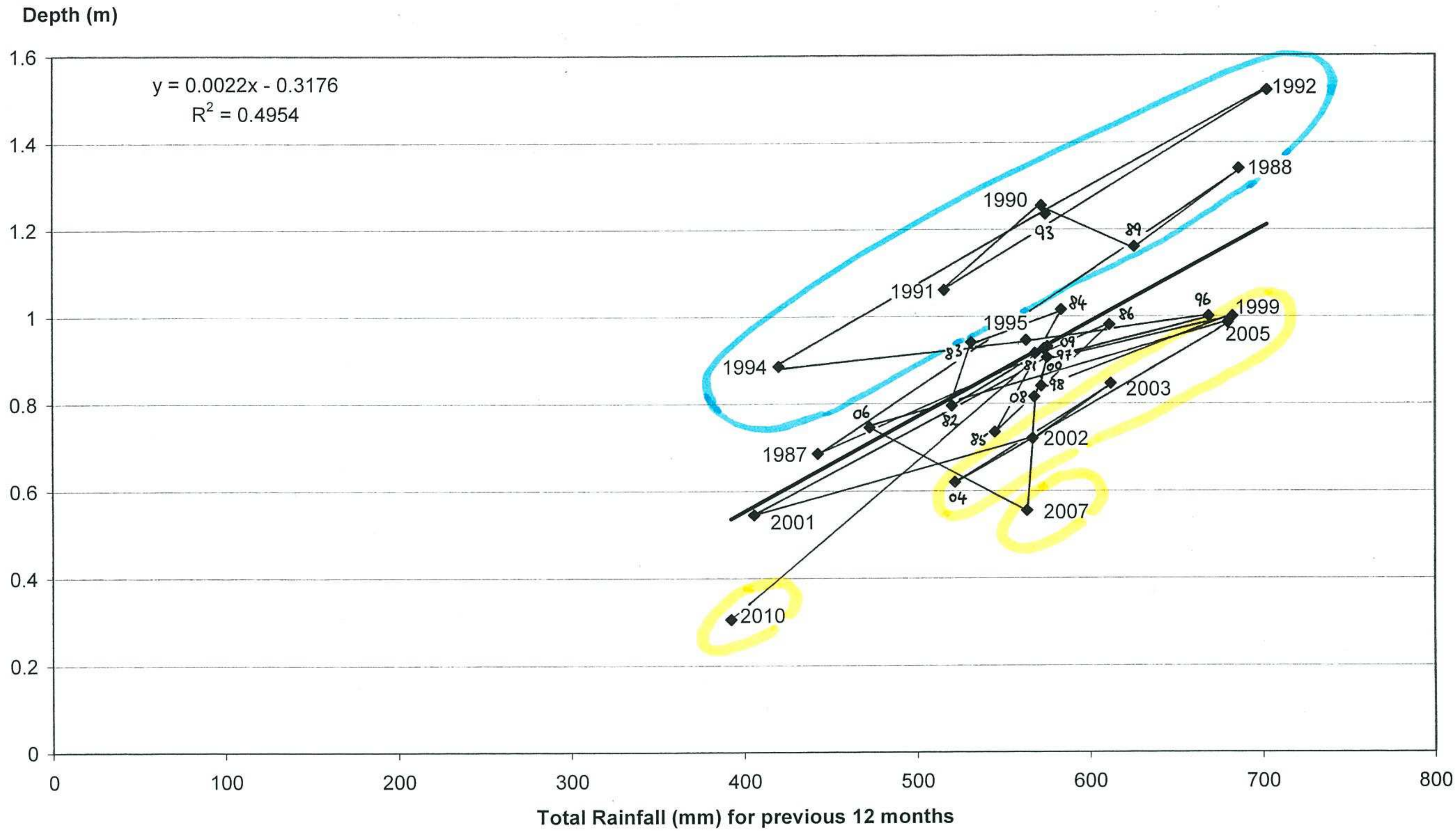


Figure 12. Regression of Nov depth medians versus corresponding '12 months prior to Nov' rainfall medians, 1981–2010 time series.

Circling with highlighter indicates Novembers with depth to rainfall ratios that are *substantially* higher (blue) or *substantially* lower (yellow) than 'average' (regression line). Connecting lines indicate chronological sequence. See Section 3.5.3 for further explanation and discussion.

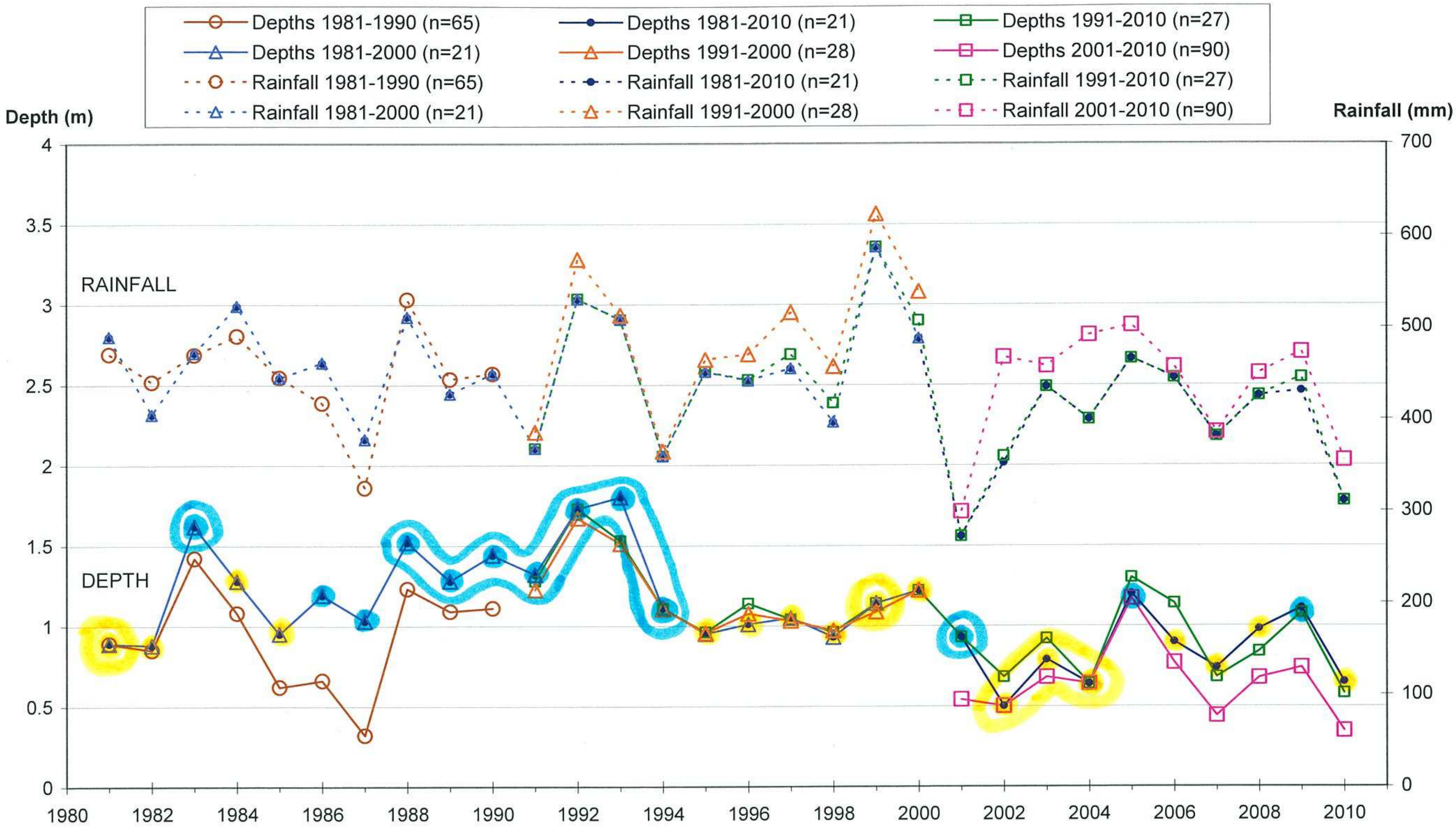


Figure 13. Septembers of higher (blue) and lower (yellow) than 'average' depth to rainfall ratios, 1981-2010 time series.

See Section 3.5.3 for explanation. Circling with highlighter indicates years when September depth to rainfall ratios are *substantially* higher (blue) or *substantially* lower (yellow) than 'average' (regression line), *as per Figure 11*. Spot highlighting simply indicates whether depth to rainfall ratios are above or below average, not necessarily substantially so. All highlighting applies only to the 1981-2010 time series. Figure 9 has been used as the graph base.

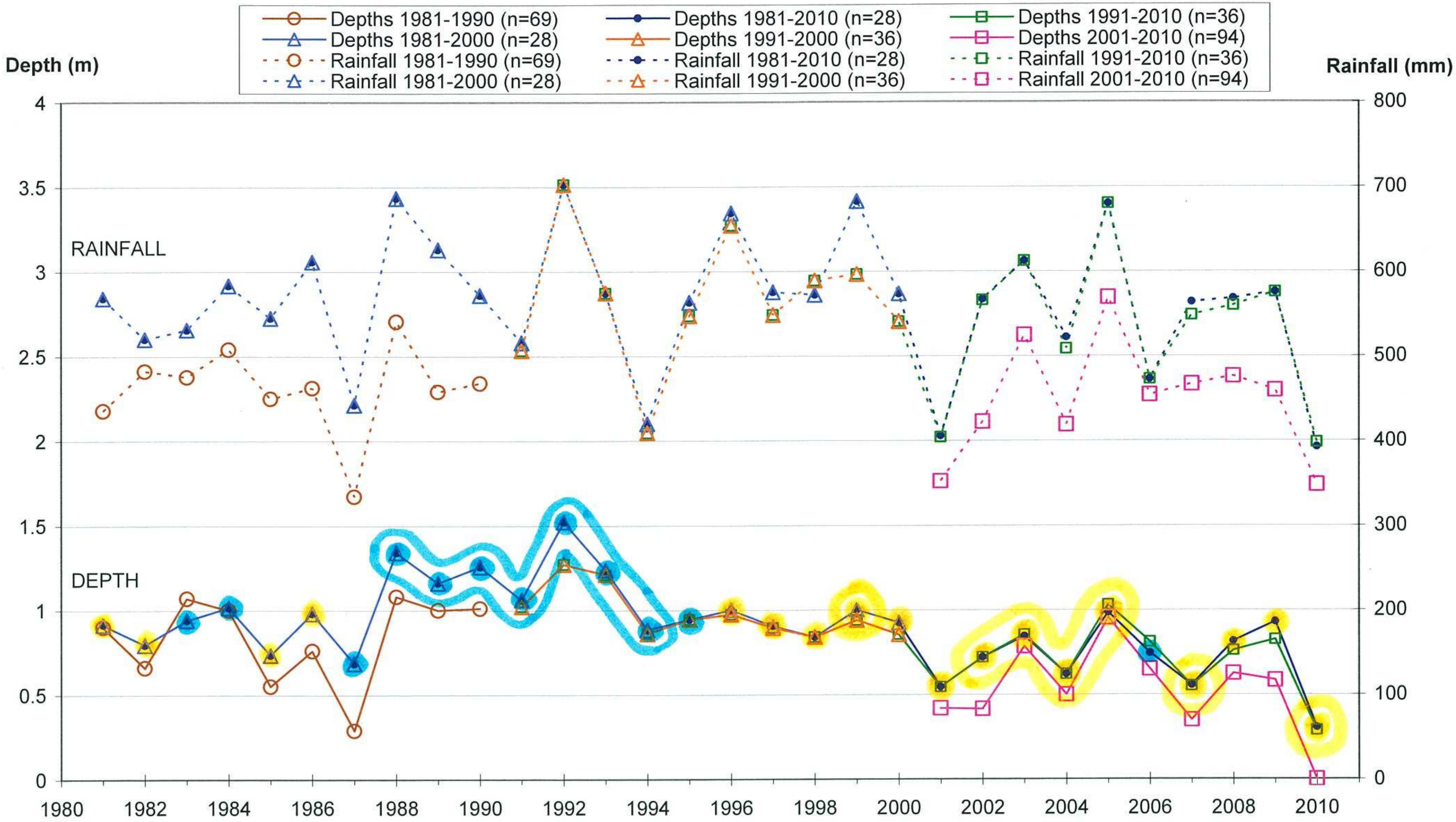


Figure 14. Novembers of higher (blue) and lower (yellow) than 'average' depth to rainfall ratios, 1981-2010 time series.

See Section 3.5.3 for explanation. Circling with highlighter indicates years when November depth to rainfall ratios are *substantially* higher (blue) or *substantially* lower (yellow) than 'average' (regression line), *as per Figure 12*. Spot highlighting simply indicates whether depth to rainfall ratios are above or below average, not necessarily substantially so. All highlighting applies only to the 1981-2010 time series. Figure 10 has been used as the graph base.

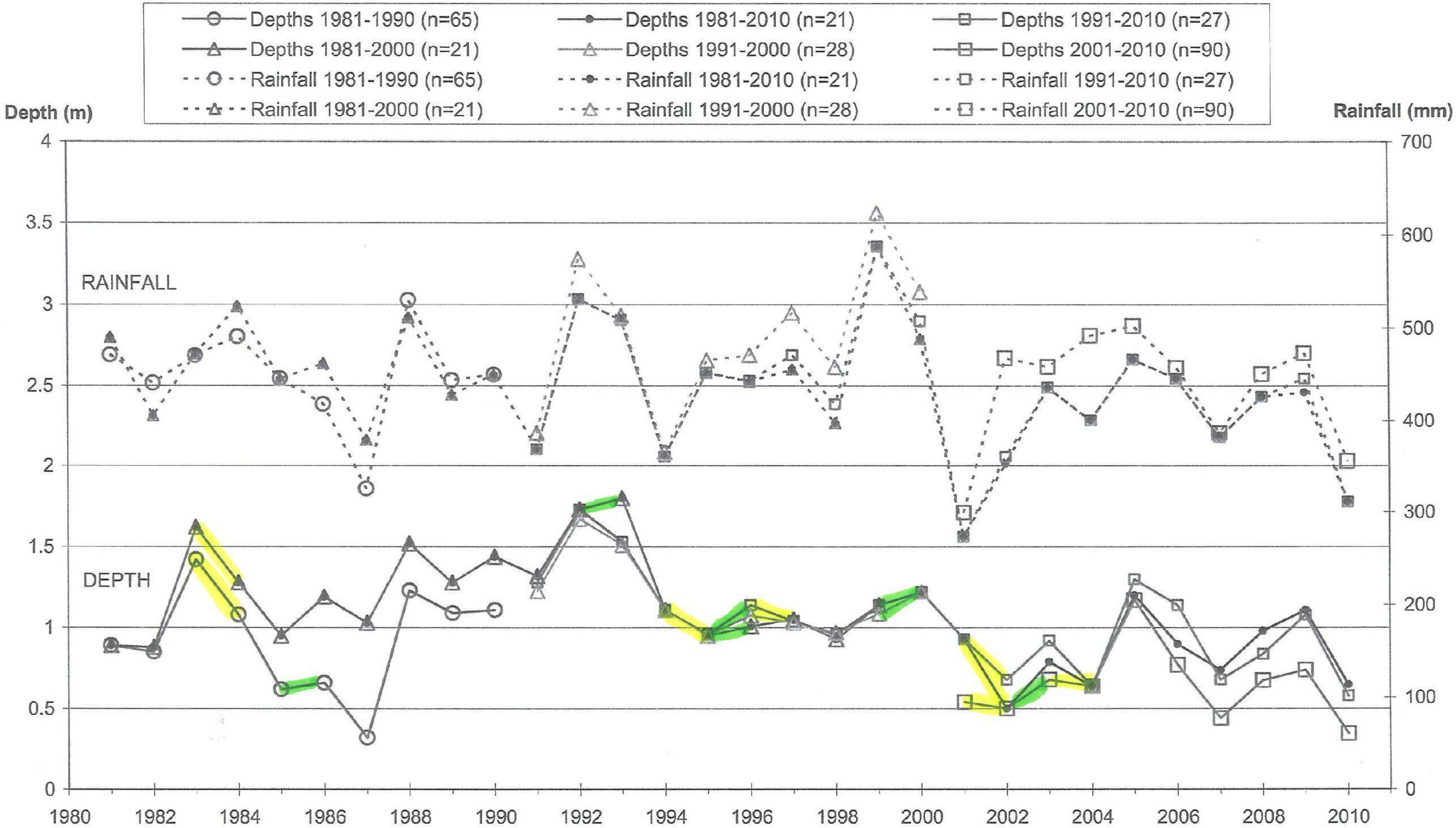


Figure 15. Directions of year-to-year changes in September depth and rainfall medians, 1981 to 2010 (all series).
Directions of change were identical in all years - except those highlighted in yellow (rainfall medians up, but depth medians down) and green (rainfall medians down, but depths median up). See Section 3.5.4 for explanation. Figure 9 has been used as the graph base.

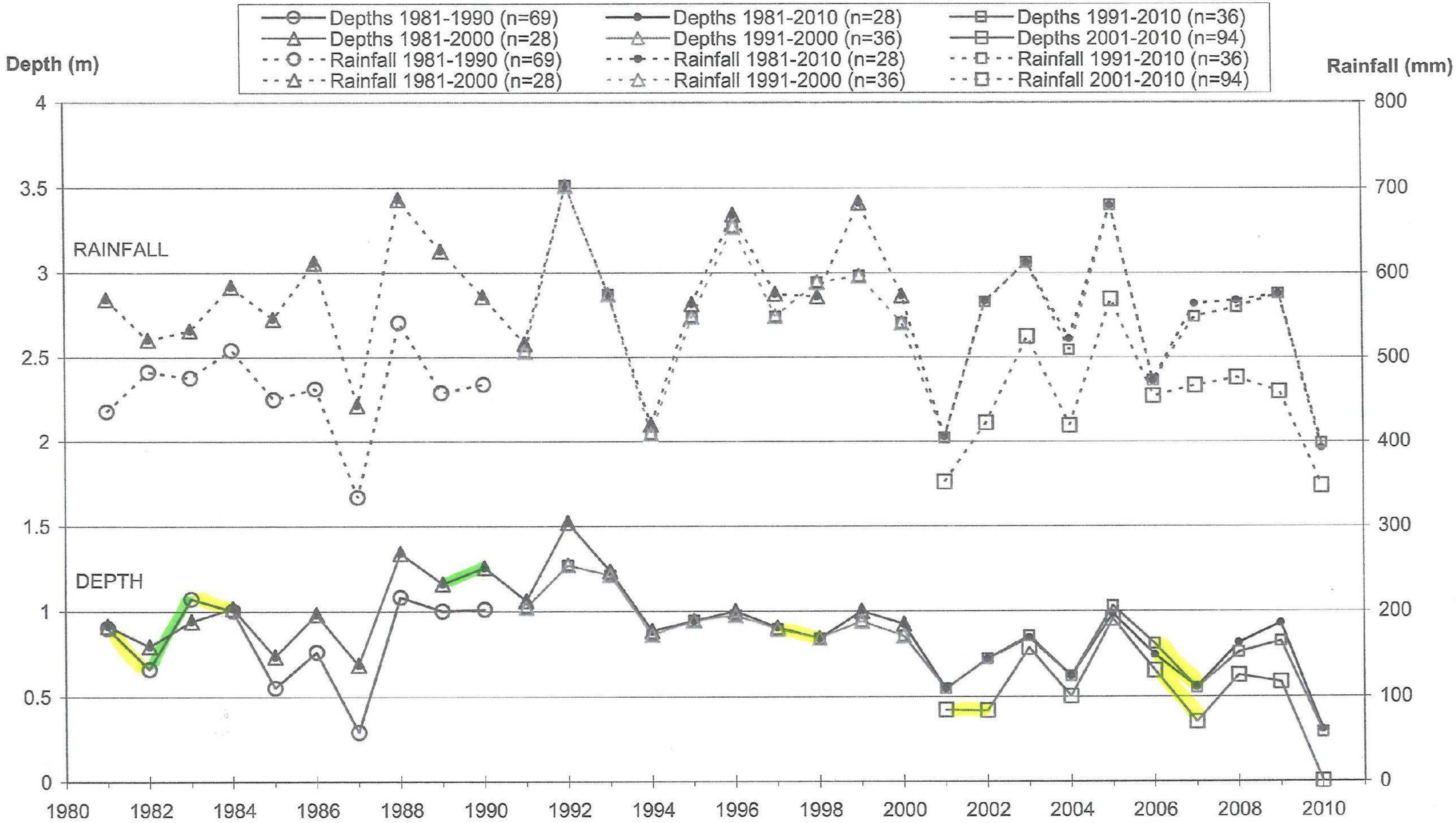


Figure 16. Directions of year-to-year changes in November depth and rainfall medians, 1981 to 2010 (all series).
Directions of change were identical in all years - except those highlighted in yellow (rainfall medians up, but depth medians down) and green (rainfall medians down, but depth medians up). See Section 3.5.4 for explanation. Figure 10 has been used as the graph base.

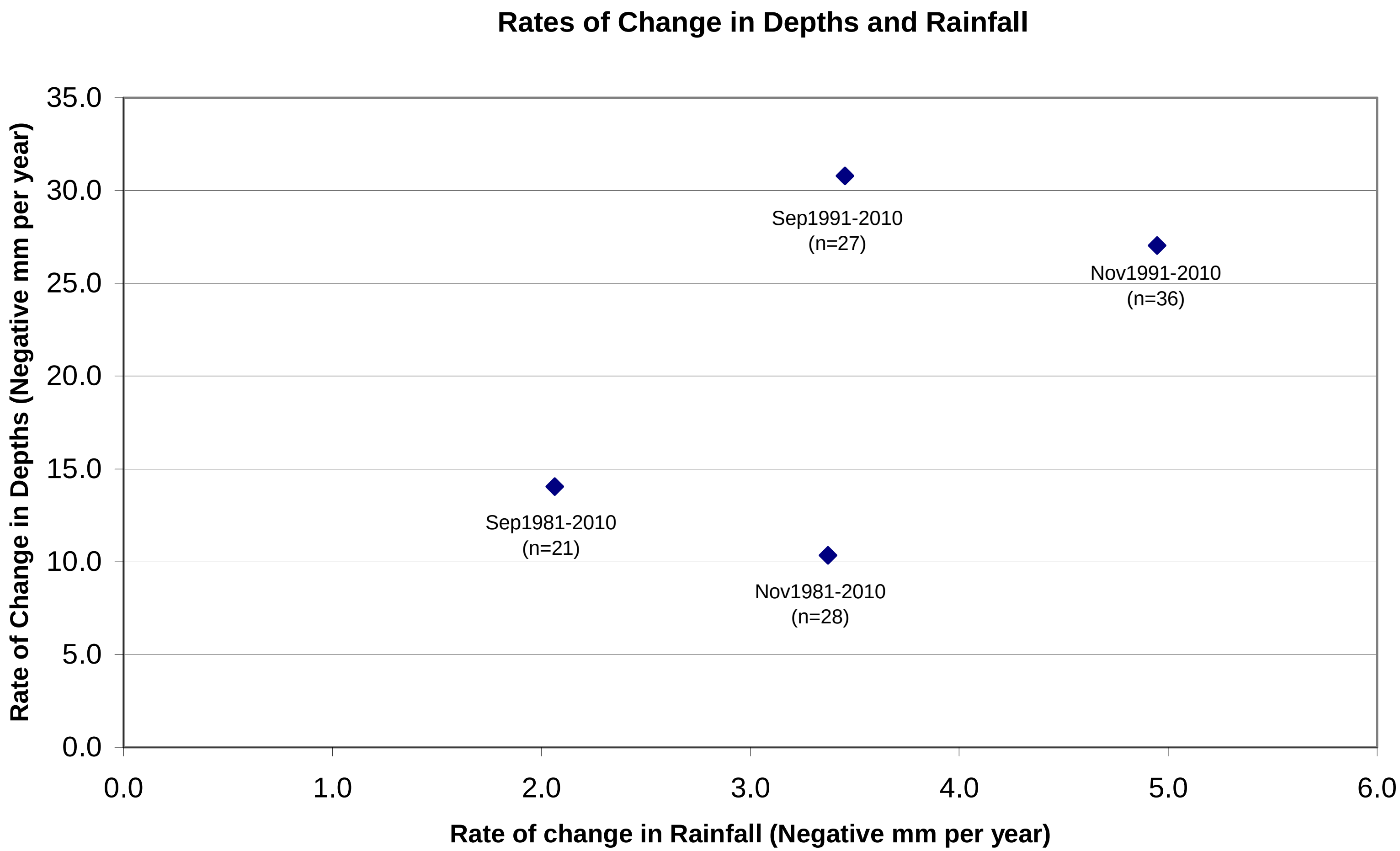
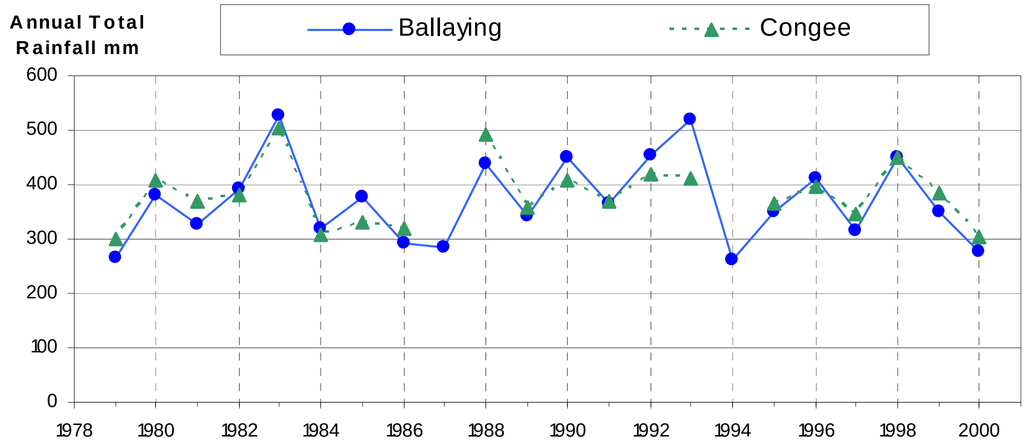


Figure 17. Rates of change in wetland depths compared with rates of change in rainfalls. (n= number of wetlands and also number of rainfall recording stations). Note that both axes are negative. Only the four periods (time series) in which statistically-significant trends in both depths and rainfalls exist are shown. This Figure has been derived from Table 5 and Appendix 70.



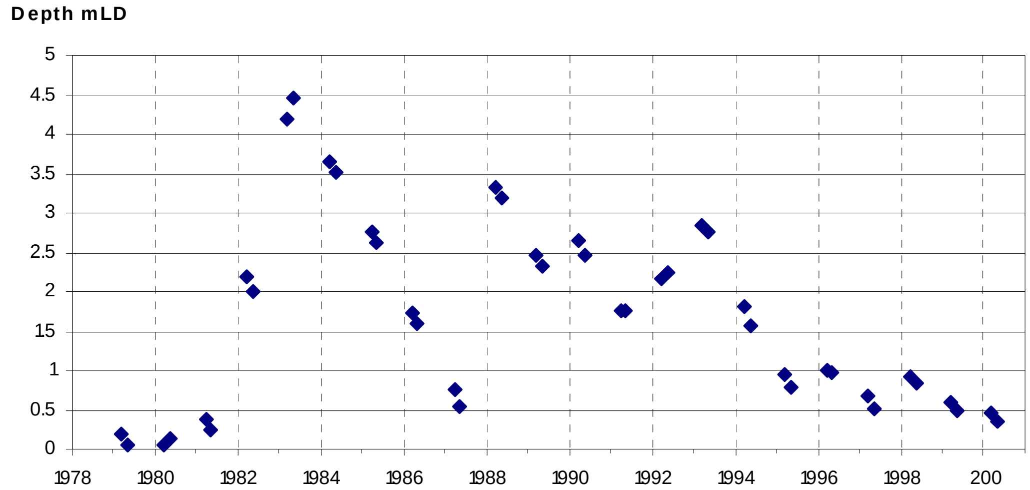


Figure 18. September and November depths of Dumbleyung Lake and annual rainfalls at two nearby recording stations (from Lane *et al.* 2004). The large increases in depths in 1982 and 1983 were due to heavy rains associated with ex-Tropical Cyclone Bruno in January 1982 and further heavy rains during winter 1983 (see Appendix 85 and discussion in Section 4.1).

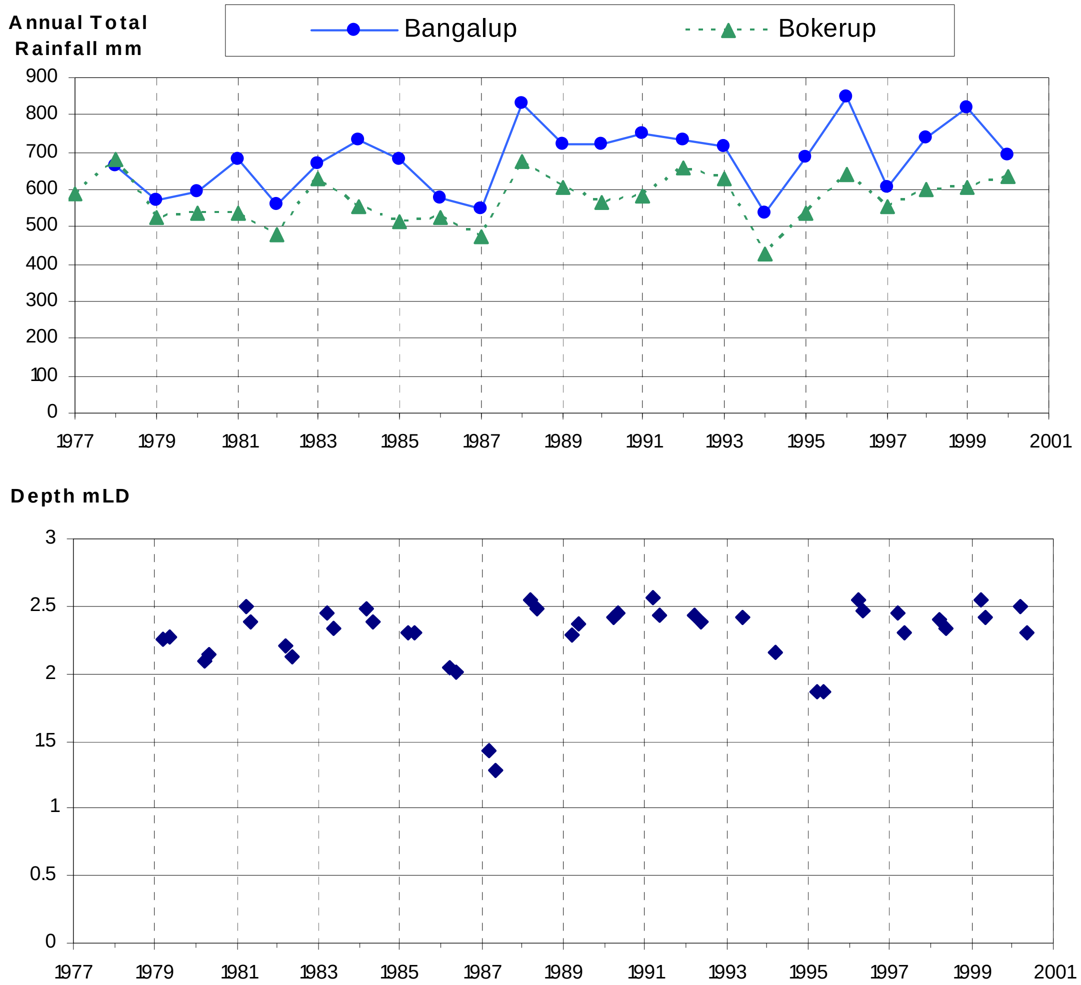


Figure 19. September and November depths of Byenup Lagoon and annual rainfalls at two nearby recording stations (from Lane *et al.* 2004). See Section 4.1 for discussion.

THIRTY YEAR (1981-2010) TRENDS IN DEPTHS AND RAINFALLS OF SOUTH-WESTERN AUSTRALIAN WETLANDS

APPENDICES

JAK Lane, YC Winchcombe & AG Clarke
Western Australian Department of Parks and Wildlife
September 2015

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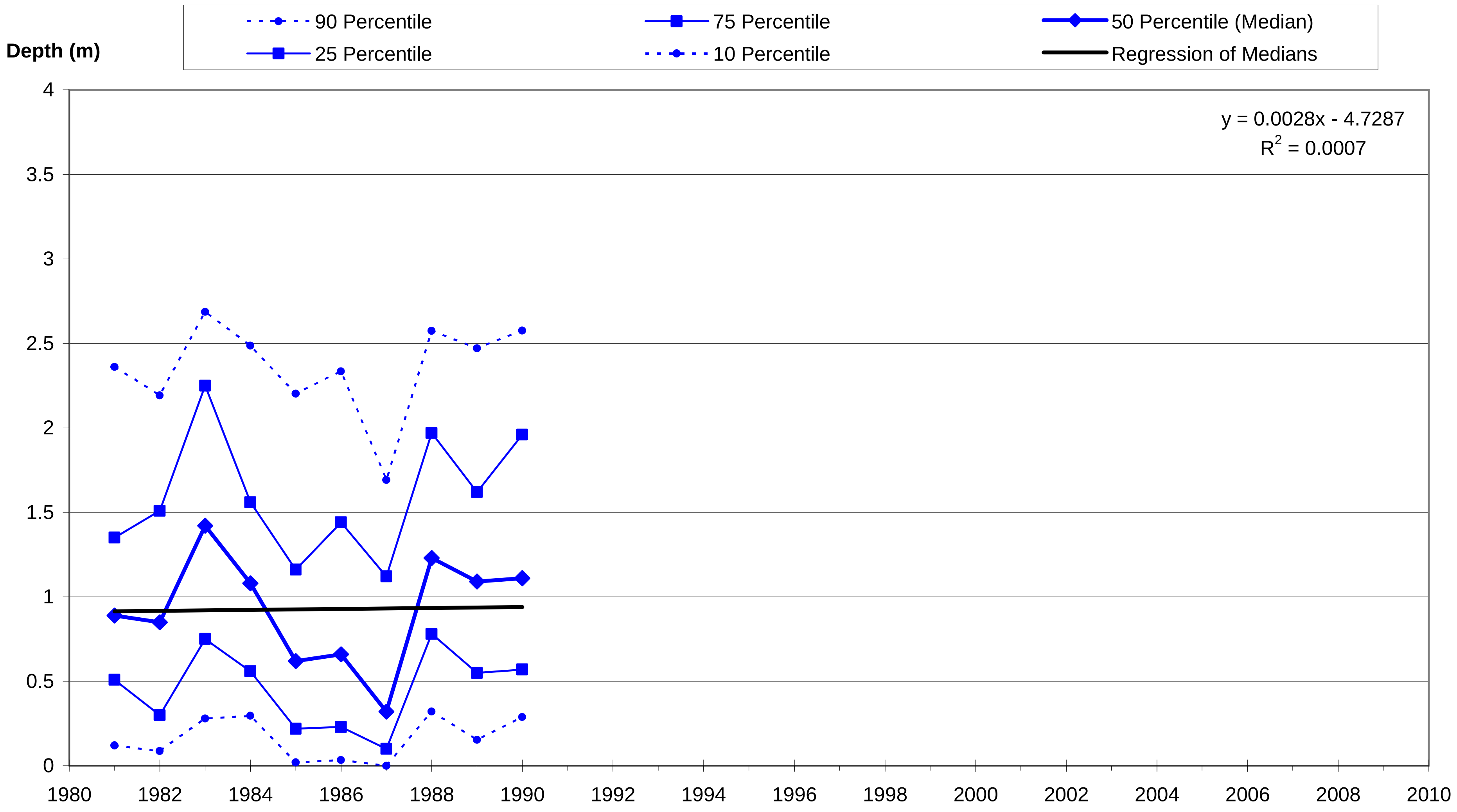
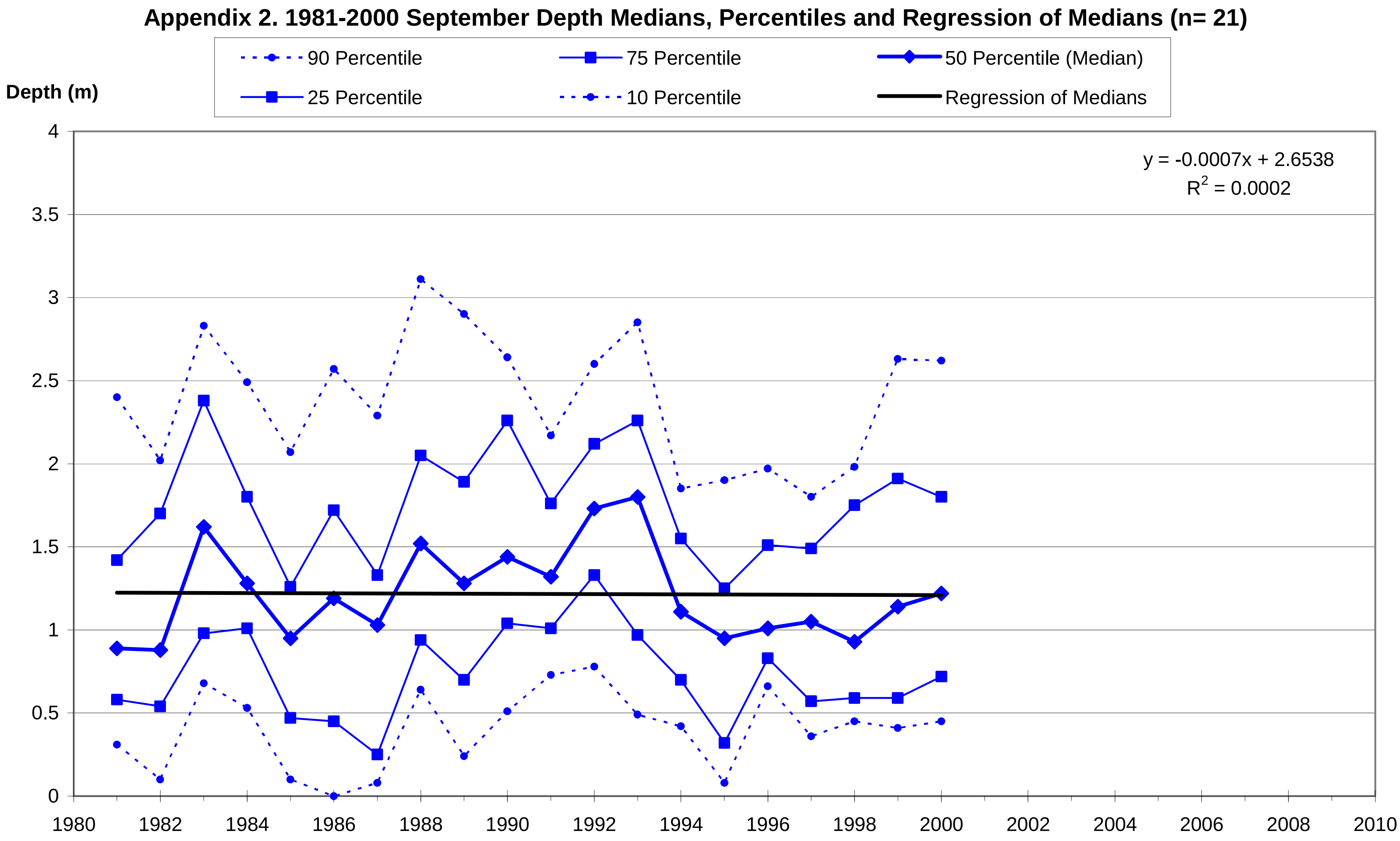
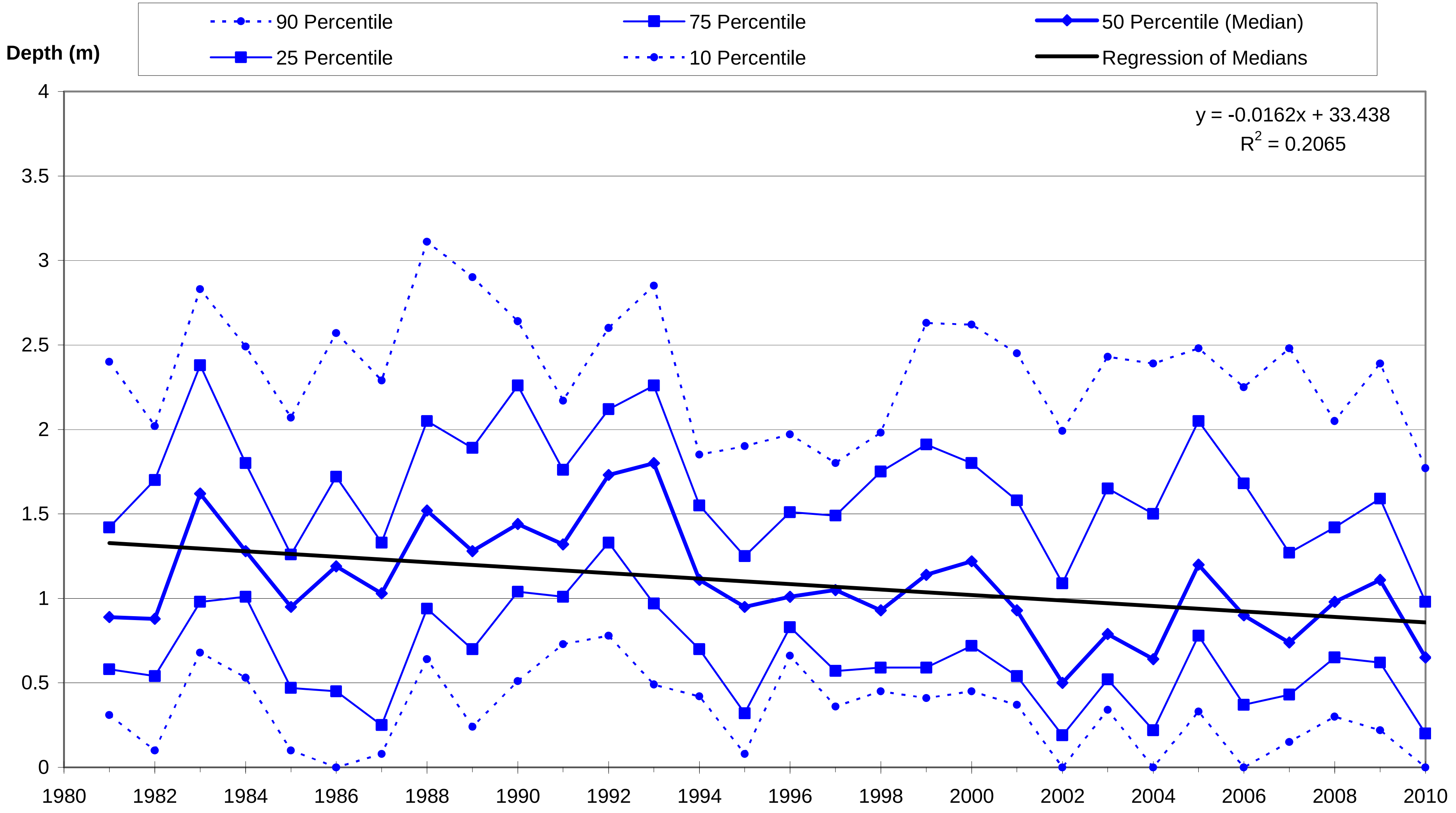
APPENDICES

Appendix 1. 1981-1990 September Depth Medians, Percentiles and Regression of Medians (n=65)

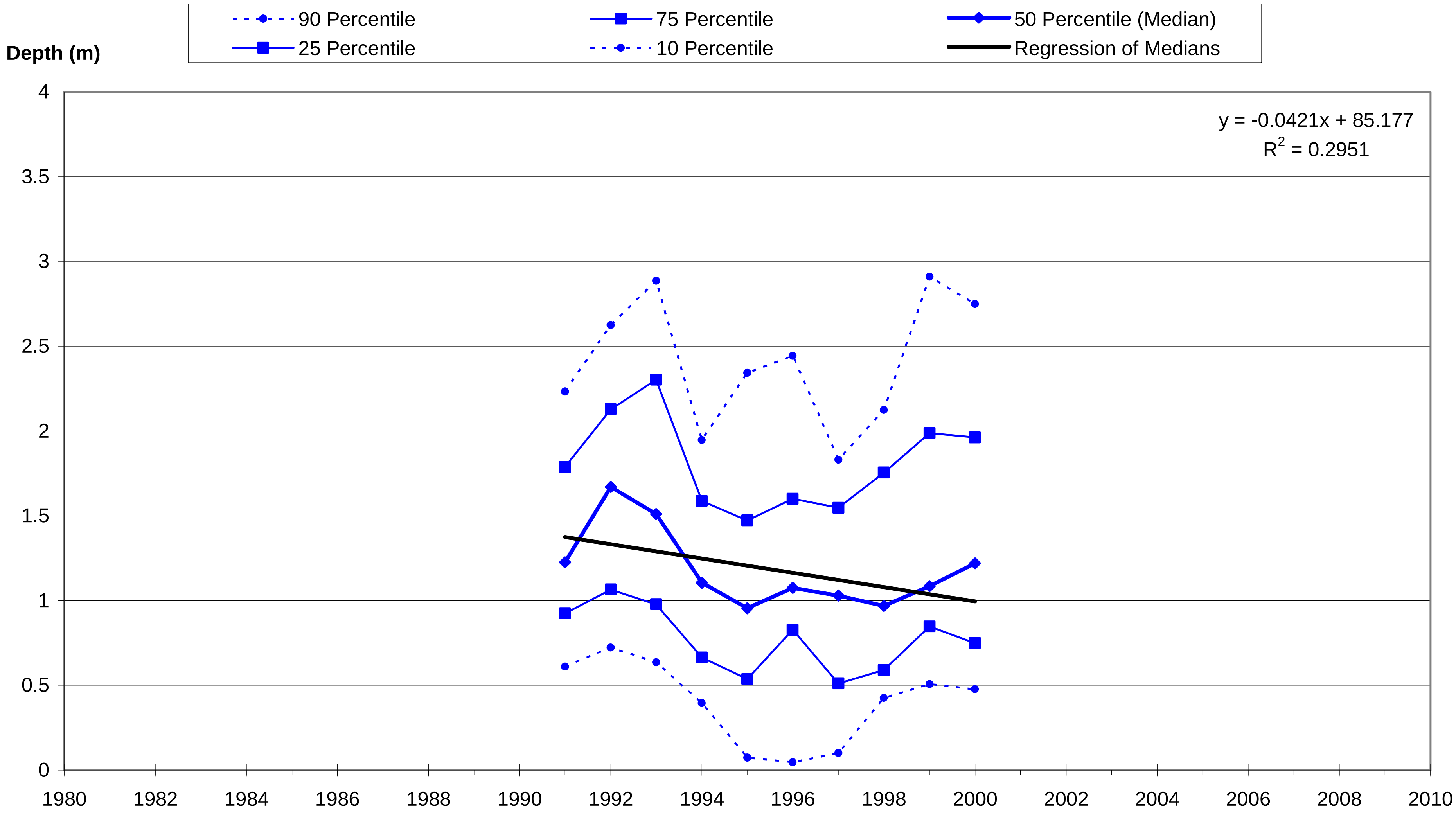



Appendix 2. 1981-2000 September Depth Medians, Percentiles and Regression of Medians (n= 21)
90 Percentile
75 Percentile
50 Percentile (Median)
25 Percentile
10 Percentile
Regression of Medians
Depth (m)
y = -0.0007x + 2.6538
R2 = 0.0002
0
0.5
1
1.5
2
2.5
3
3.5
4
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010

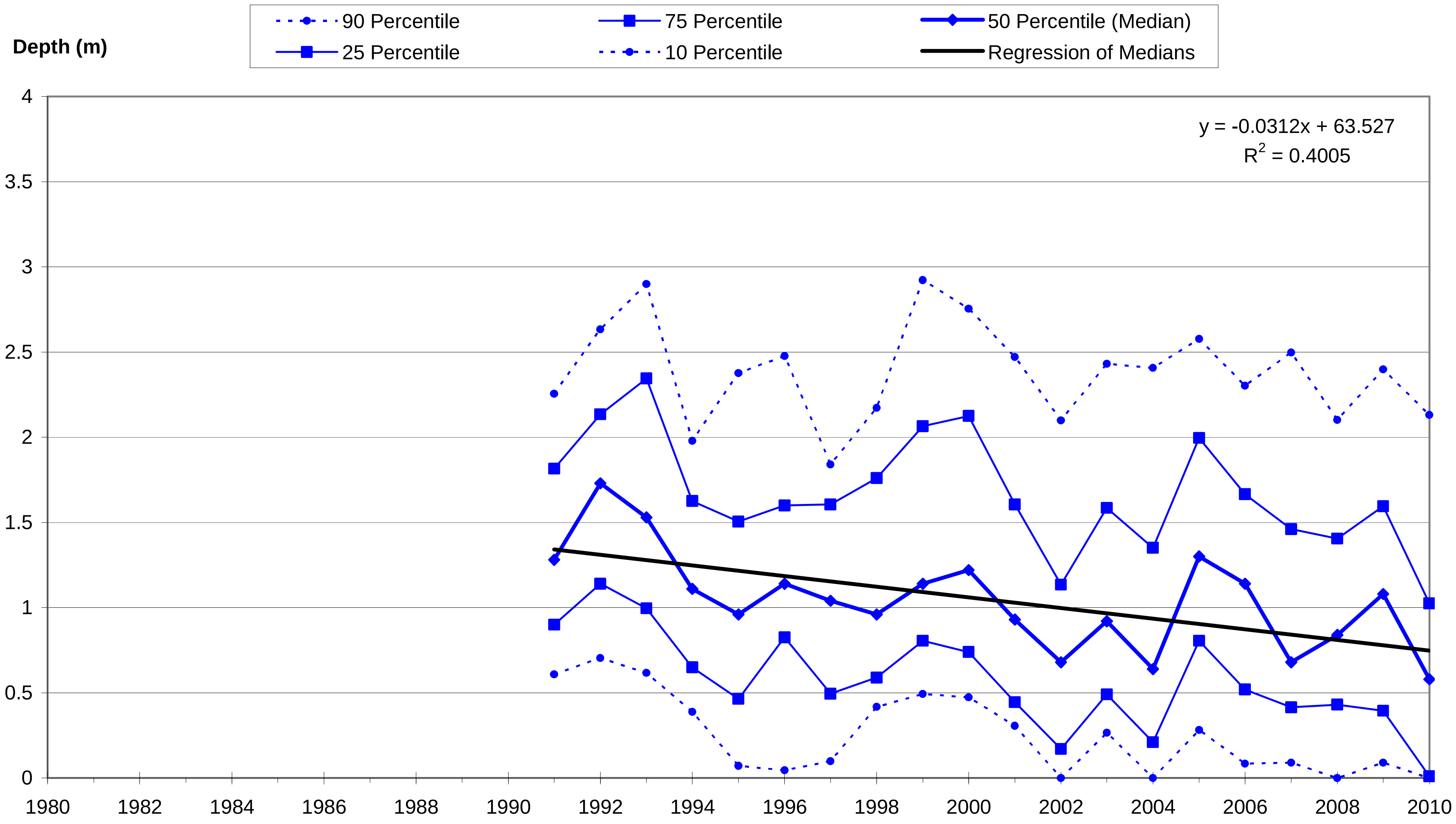
Appendix 3. 1981-2010 September Depth Medians, Percentiles and Regression of Medians (n=21)



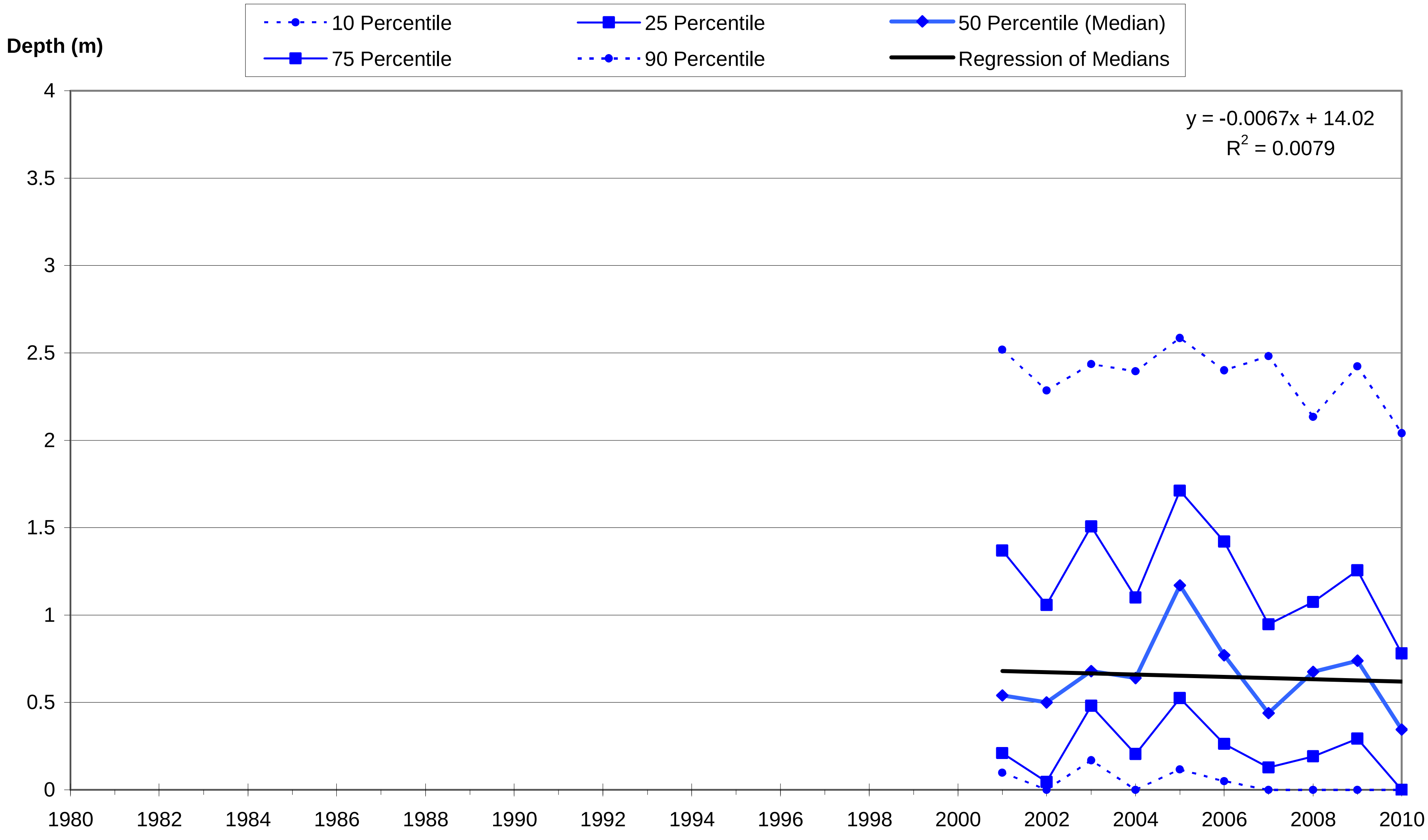
Appendix 4. 1991-2000 September Depth Medians, Percentiles and Regression of Medians (n=28)



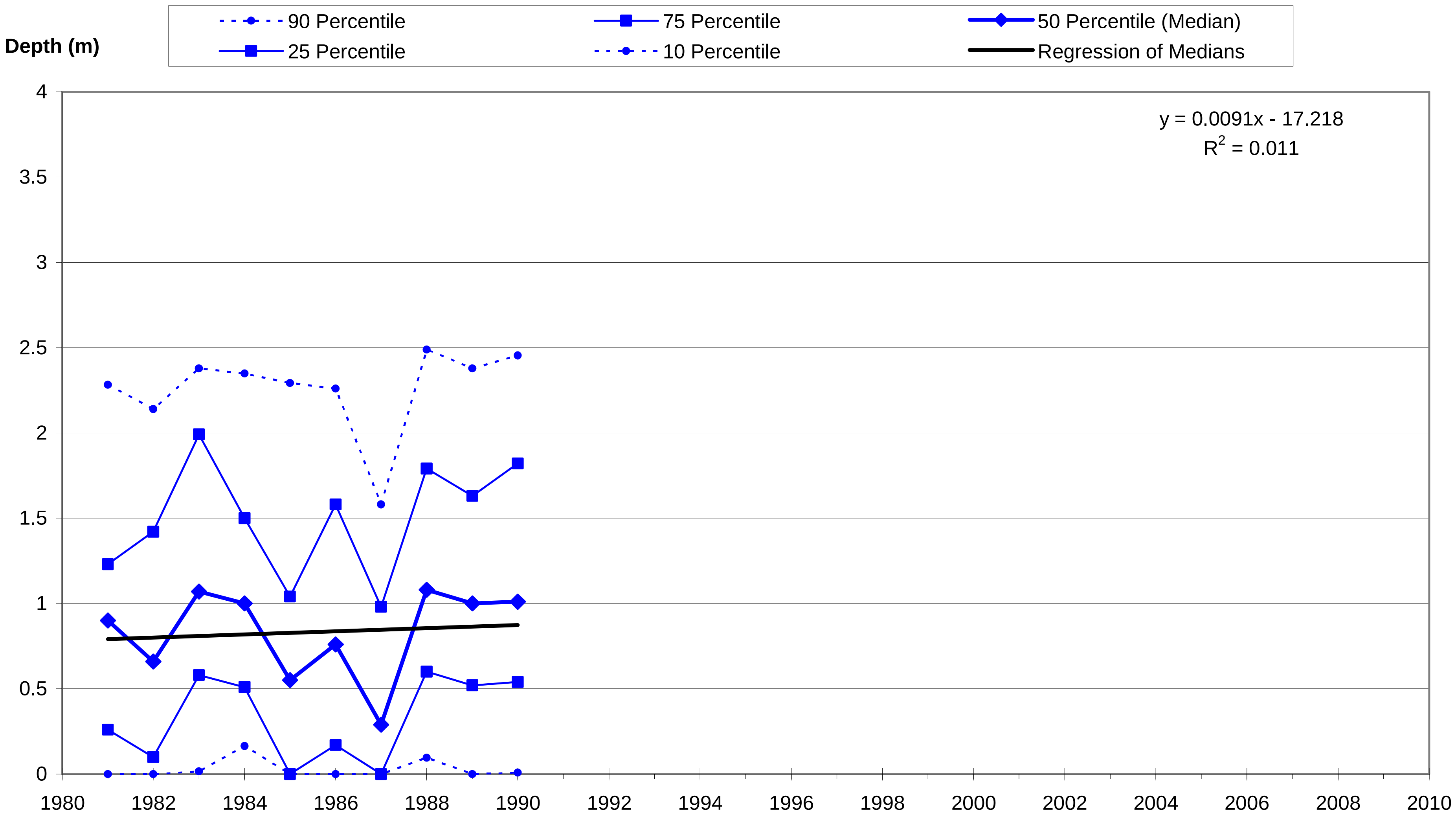
Appendix 5. 1991-2010 September Depth Medians, Percentiles and Regression of Medians (n=27)



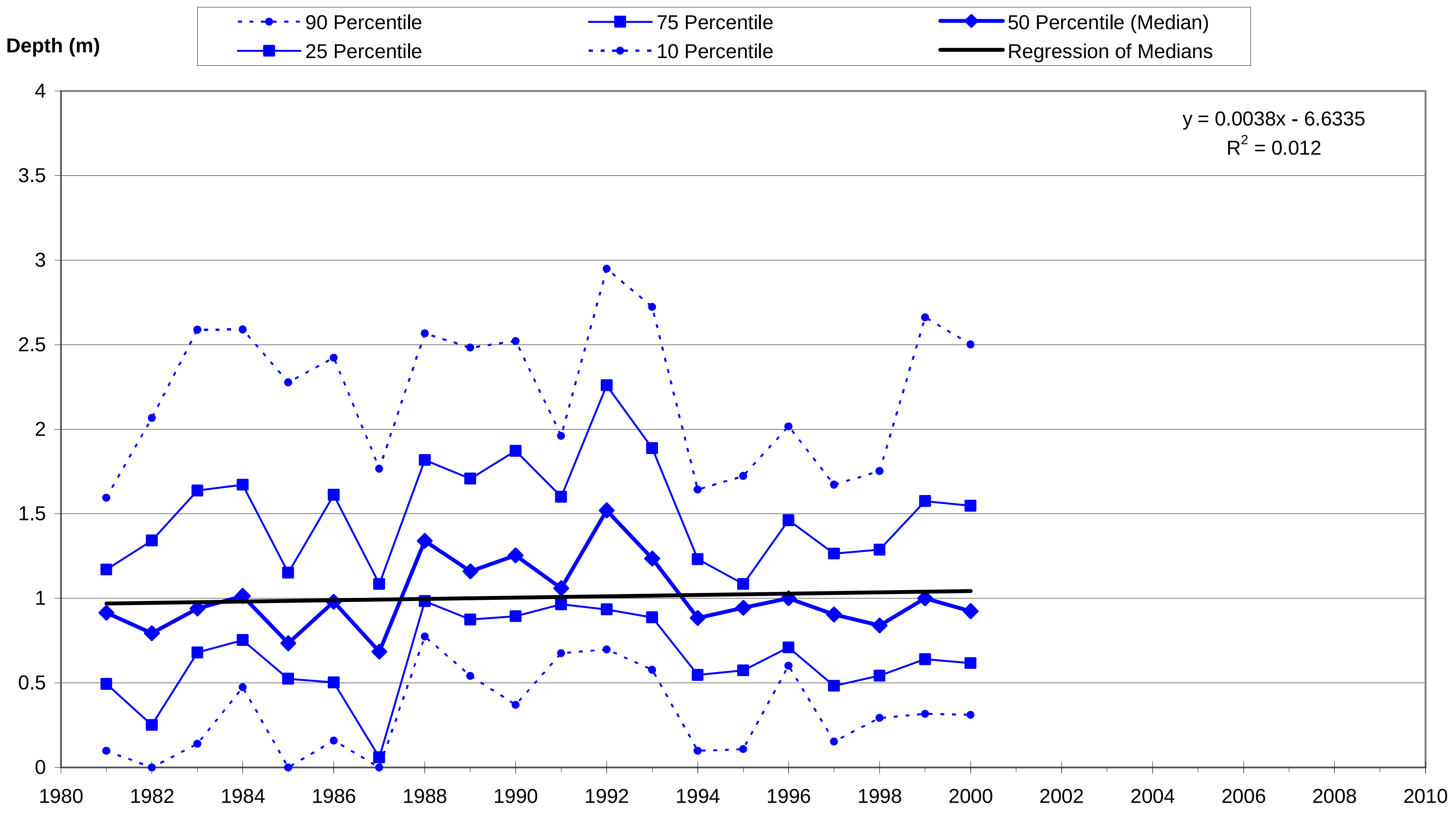
Appendix 6. 2001-2010 September Depth Medians, Percentiles and Regression of Medians (n=90)



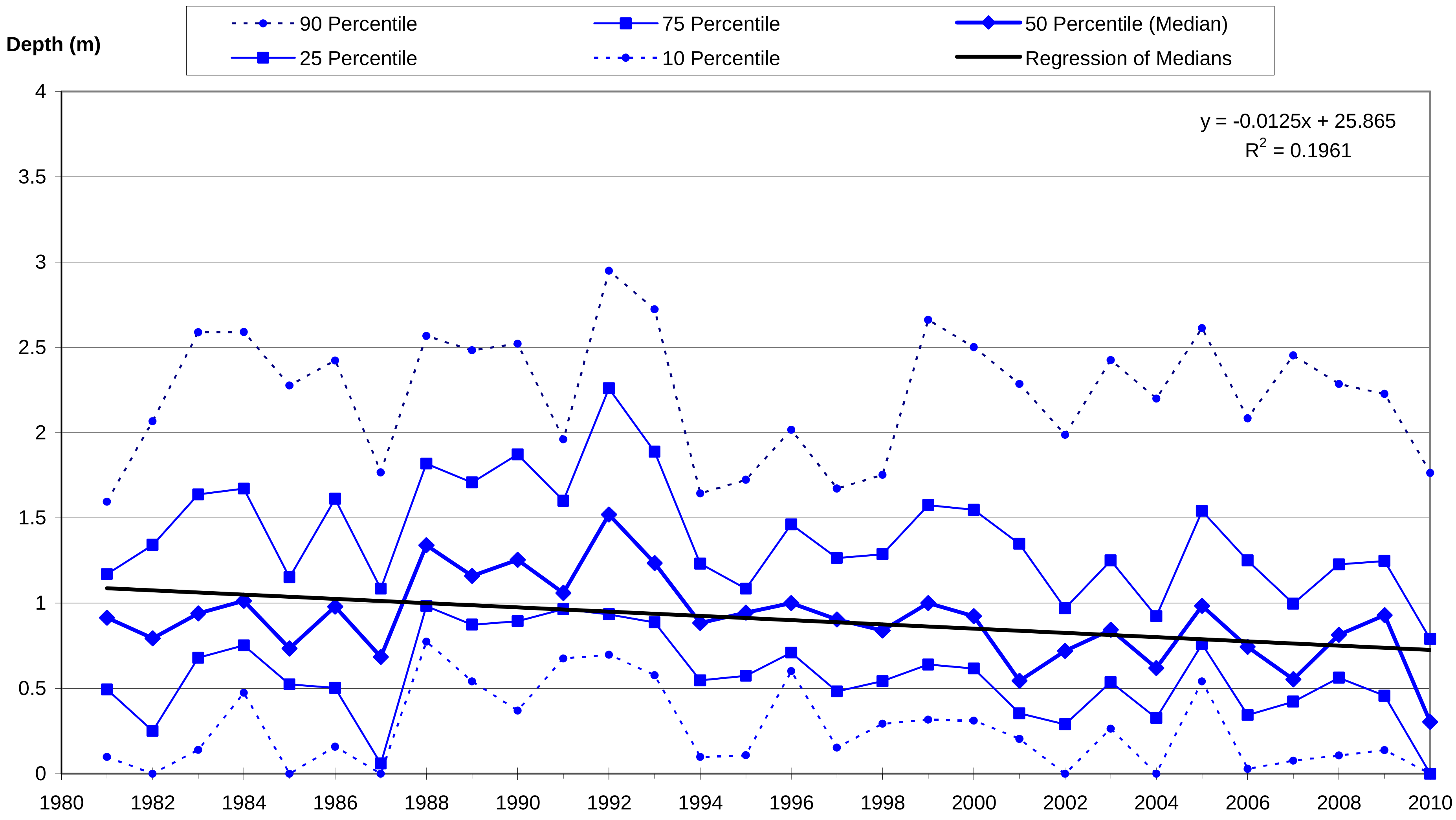
Appendix 7. 1981-1990 November Depth Medians, Percentiles and Regression of Medians (n= 69)

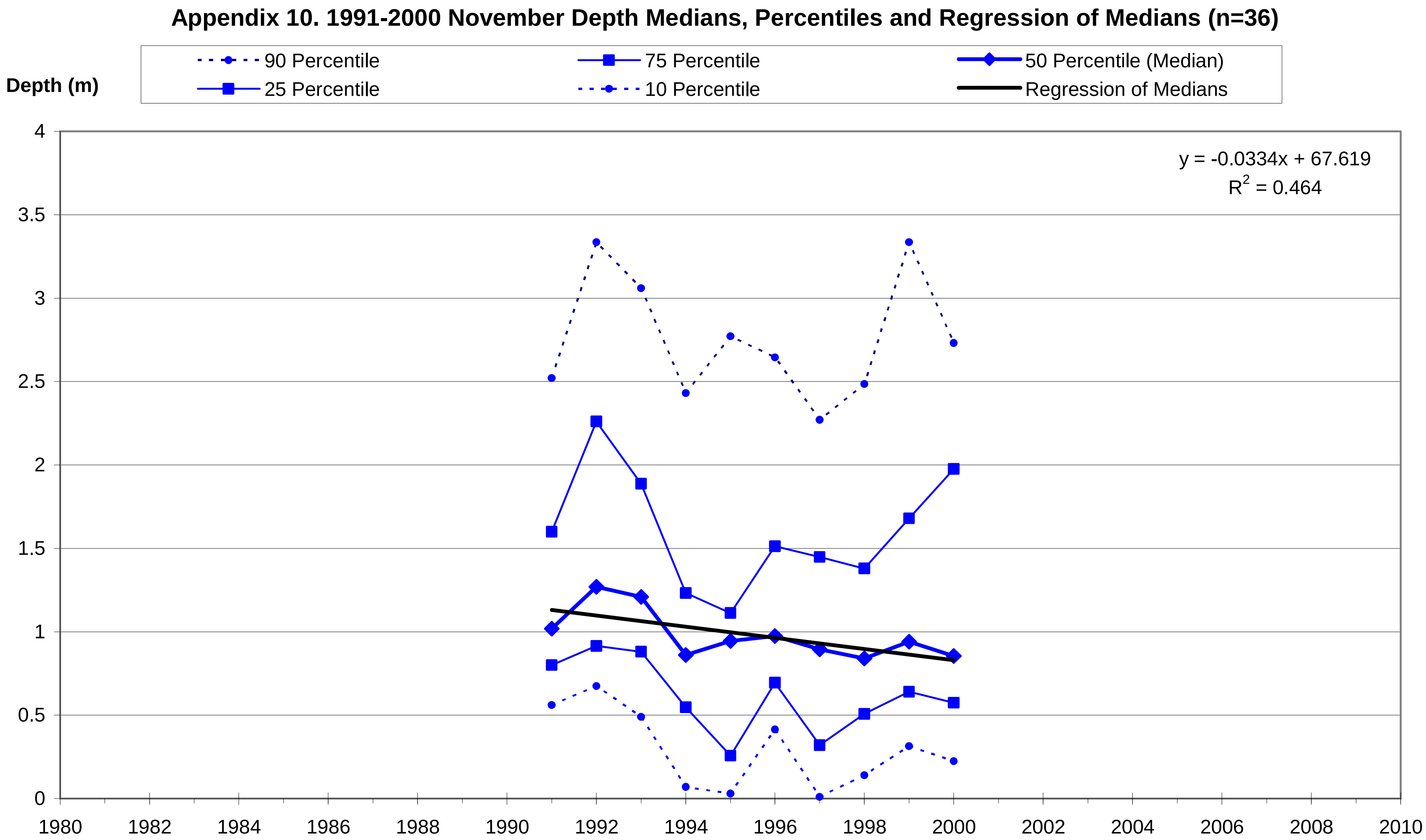


Appendix 8. 1981-2000 November Depth Medians, Percentiles and Regression of Medians (n=28)



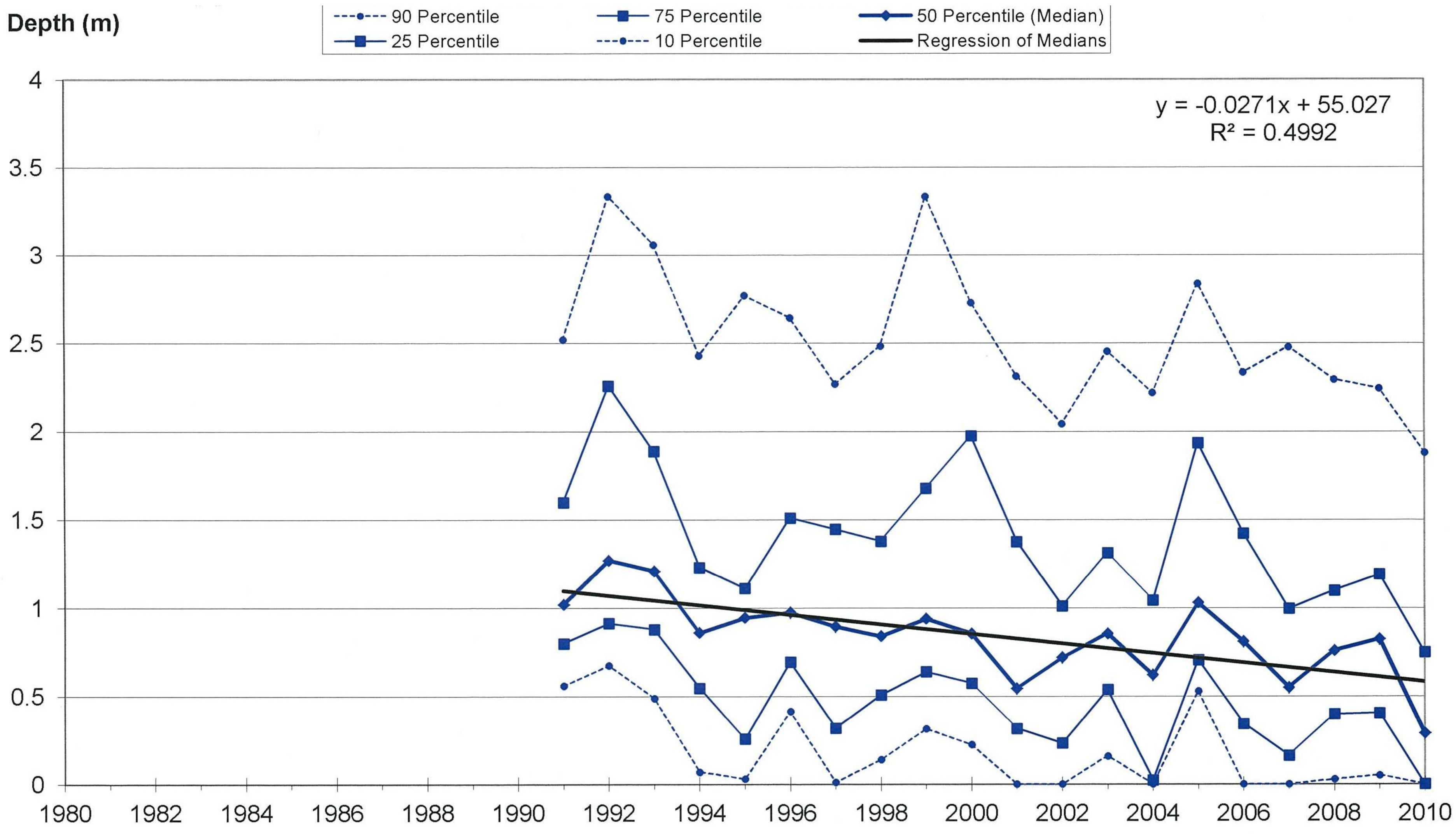
Appendix 9. 1981-2010 November Depth Medians, Percentiles and Regression of Medians (n= 28)

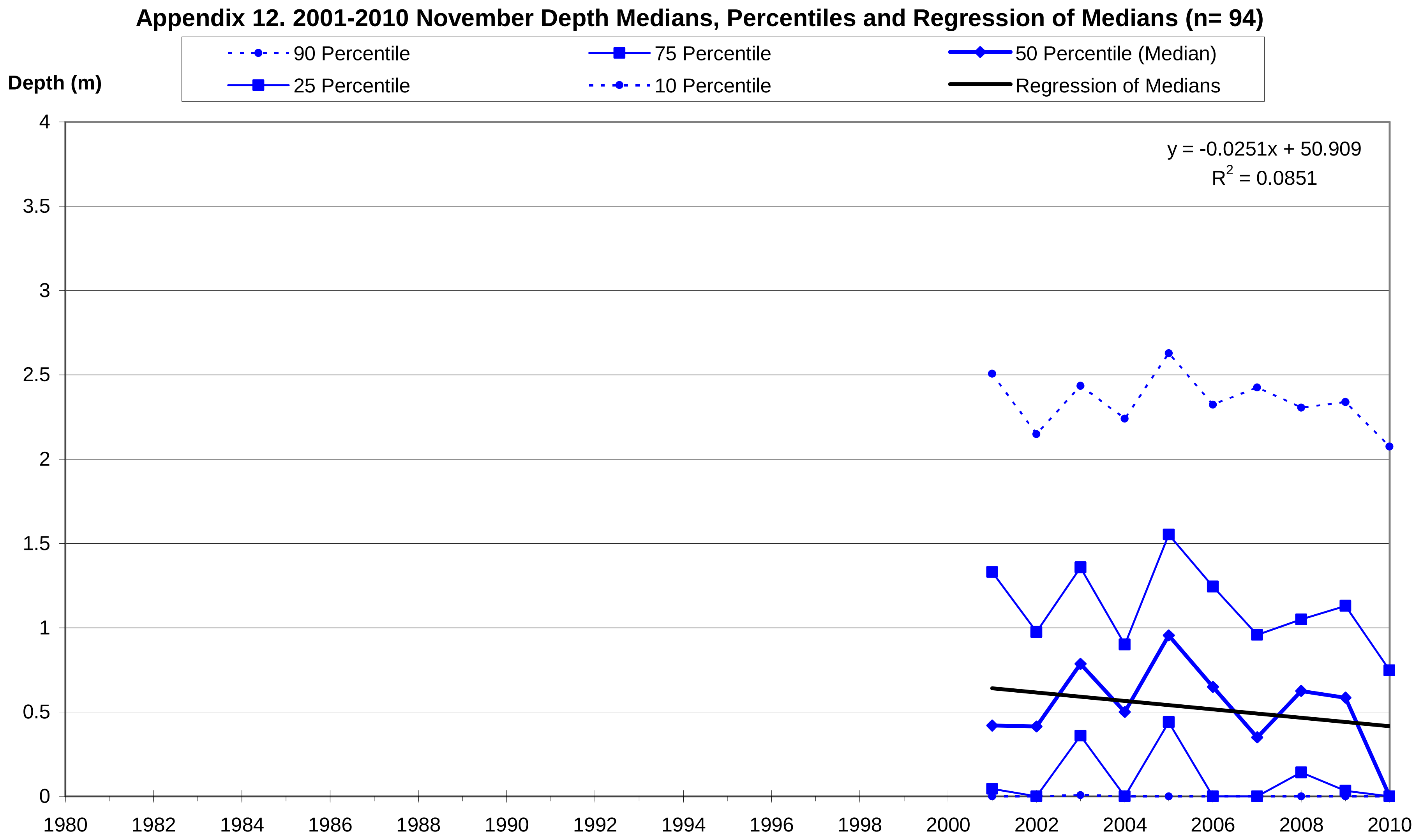




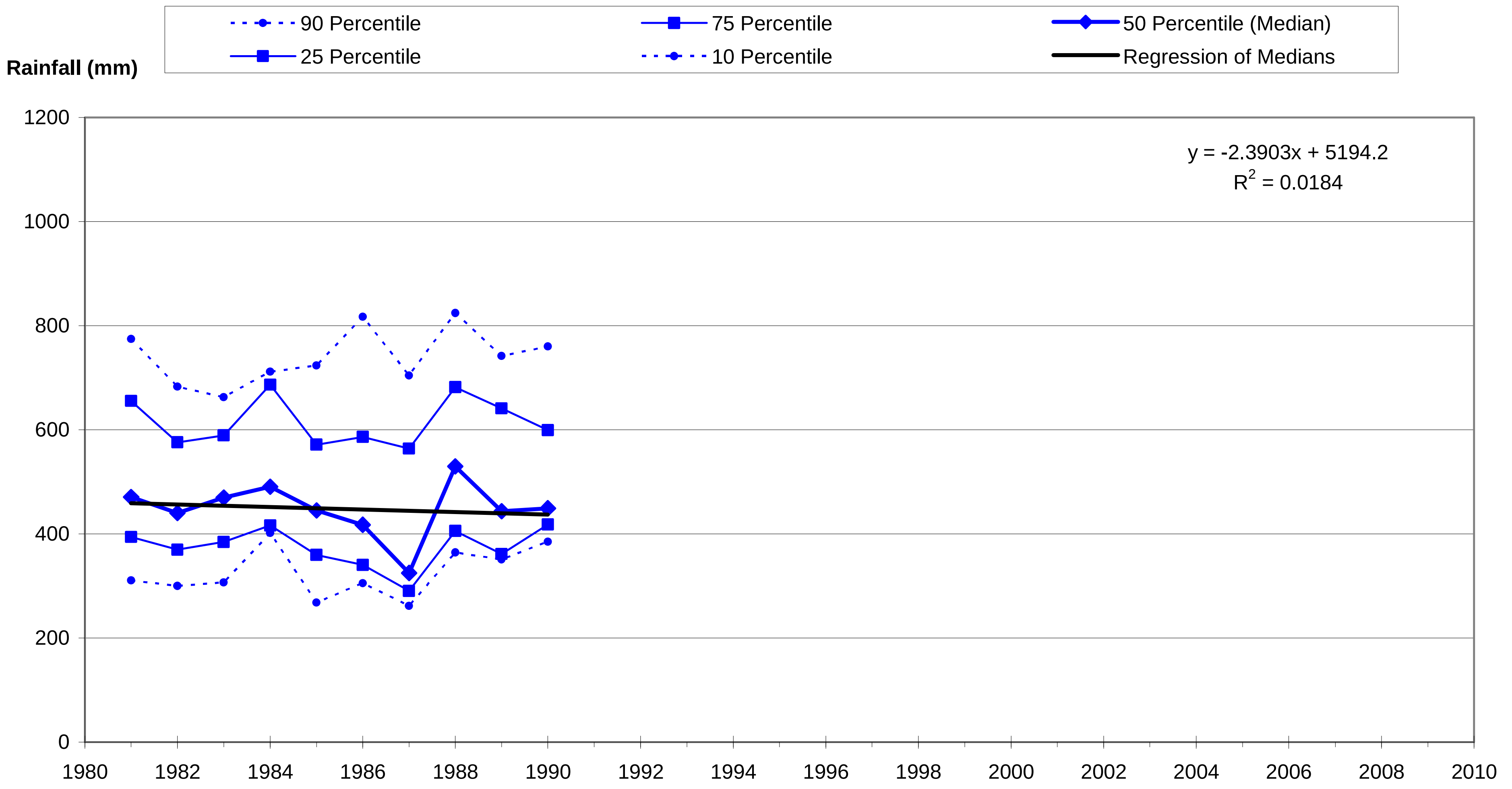
Appendix 10. 1991-2000 November Depth Medians, Percentiles and Regression of Medians (n=36)
Depth (m)
90 Percentile
75 Percentile
50 Percentile (Median)
25 Percentile
10 Percentile
Regression of Medians
y = -0.0334x + 67.619
R2 = 0.464
4
3.5
3
2.5
2
1.5
1
0.5
0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010

APPENDIX 11. 1991-2010 November Depth Medians, Percentiles and Regression of Medians (n=36)

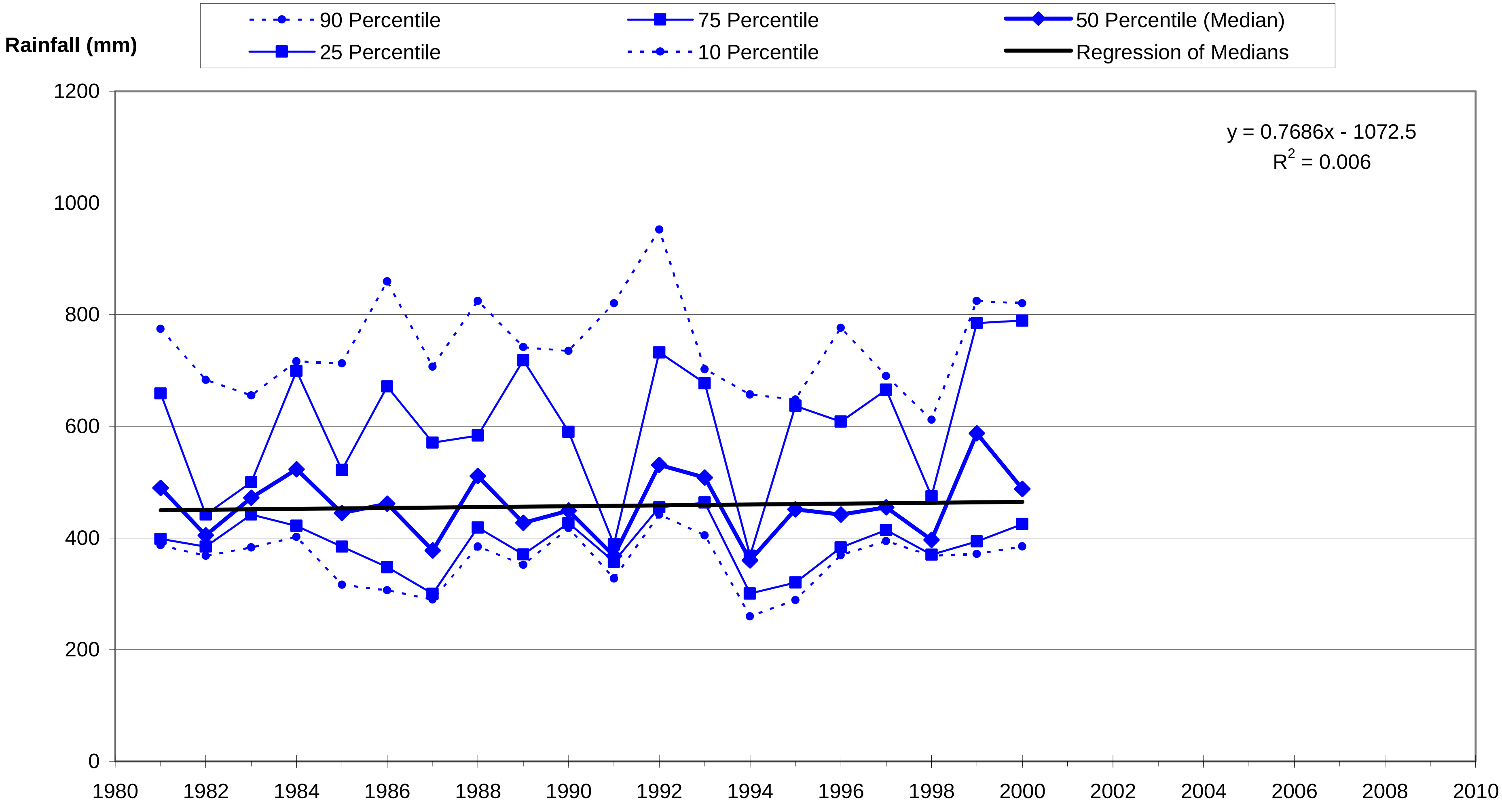



Appendix 12. 2001-2010 November Depth Medians, Percentiles and Regression of Medians (n= 94)
Depth (m)
90 Percentile
75 Percentile
50 Percentile (Median)
25 Percentile
10 Percentile
Regression of Medians
y = -0.0251x + 50.909
R^2 = 0.0851
4
3.5
3
2.5
2
1.5
1
0.5
0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010

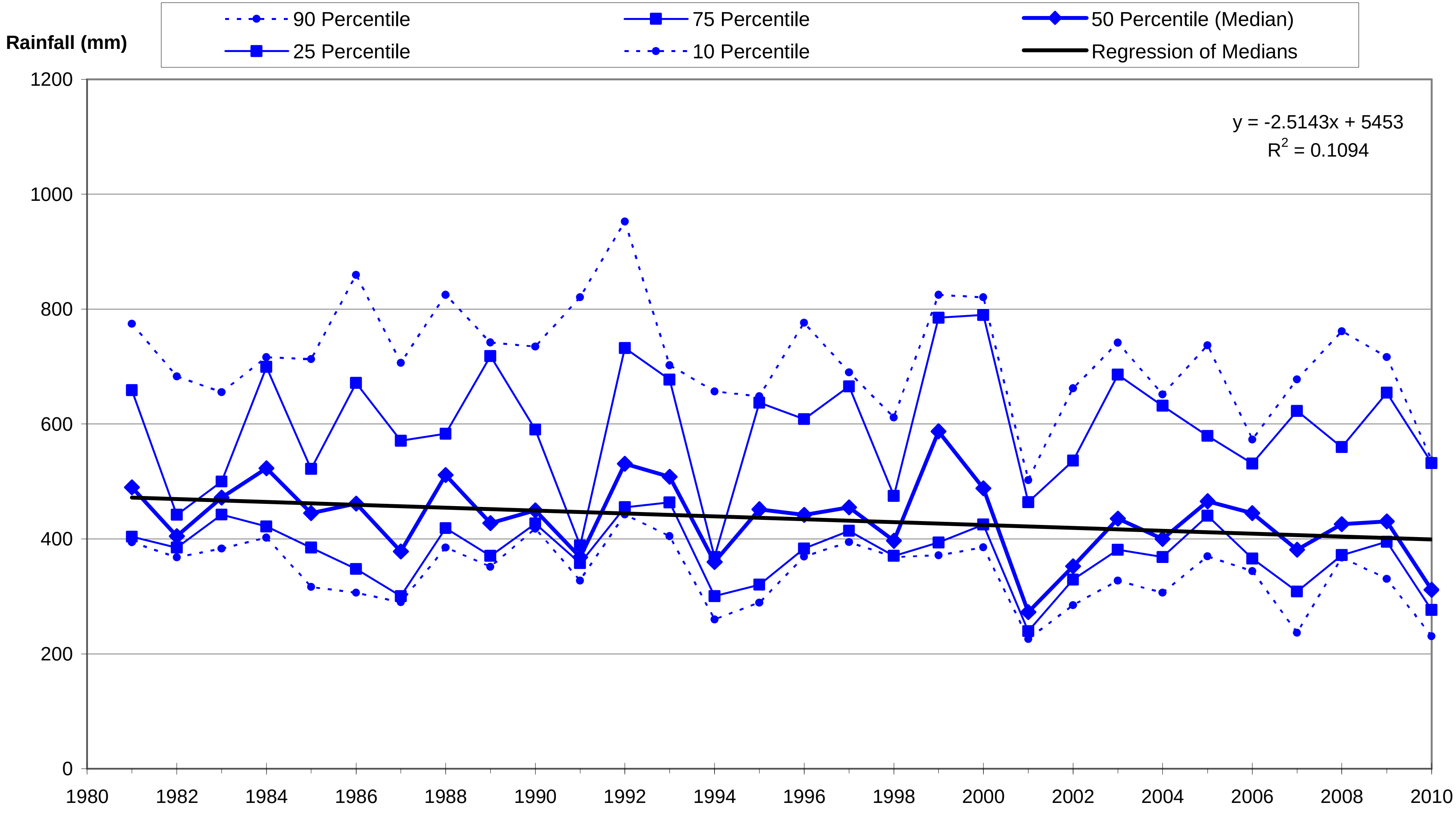
Appendix 13. 1981-1990 '12 Months prior to September' Rainfall Medians, Percentiles and Regression of Medians (n=65)



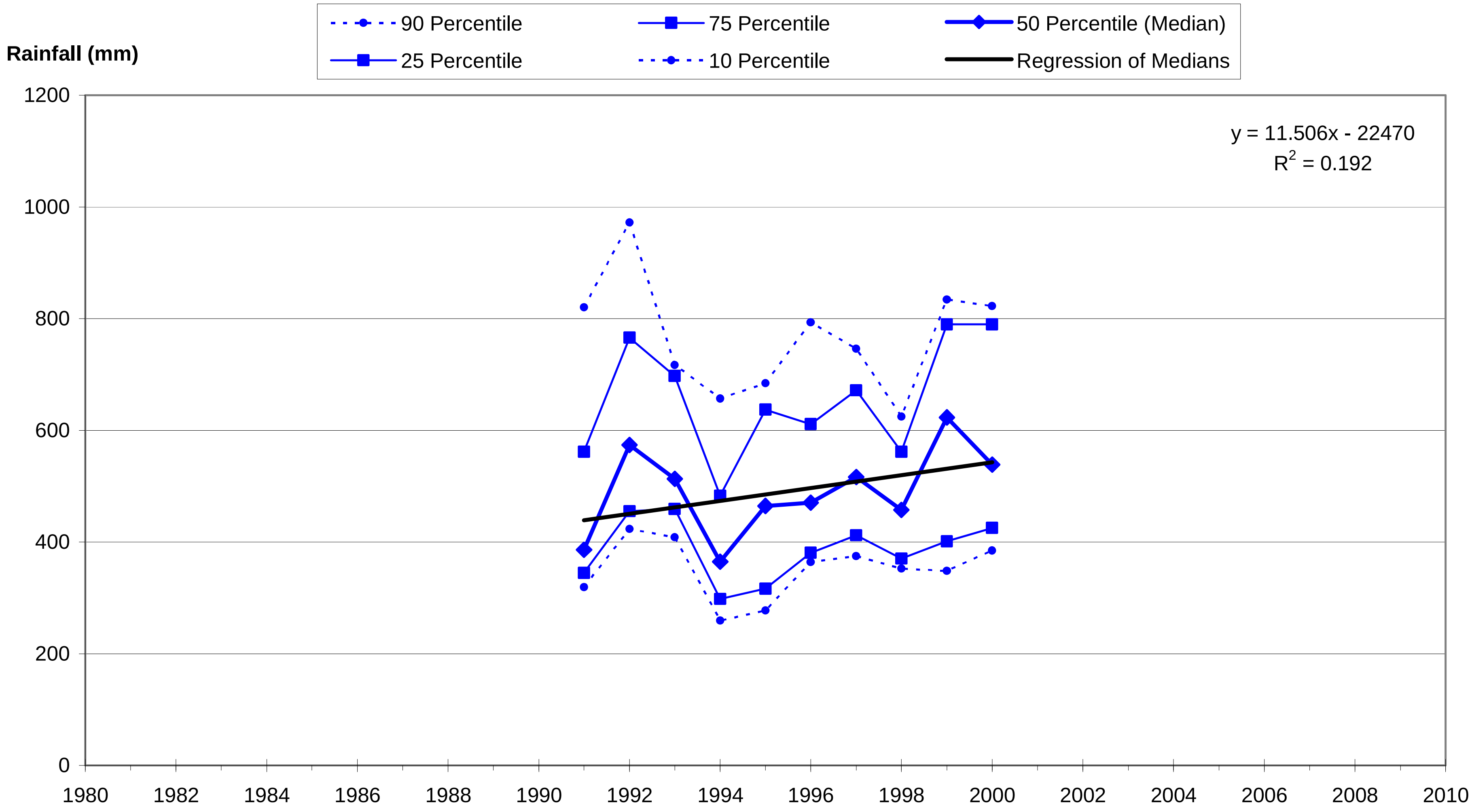
Appendix 14. 1981-2000 '12 Months prior to September' Rainfall Medians, Percentiles and Regression of Medians (n=21)



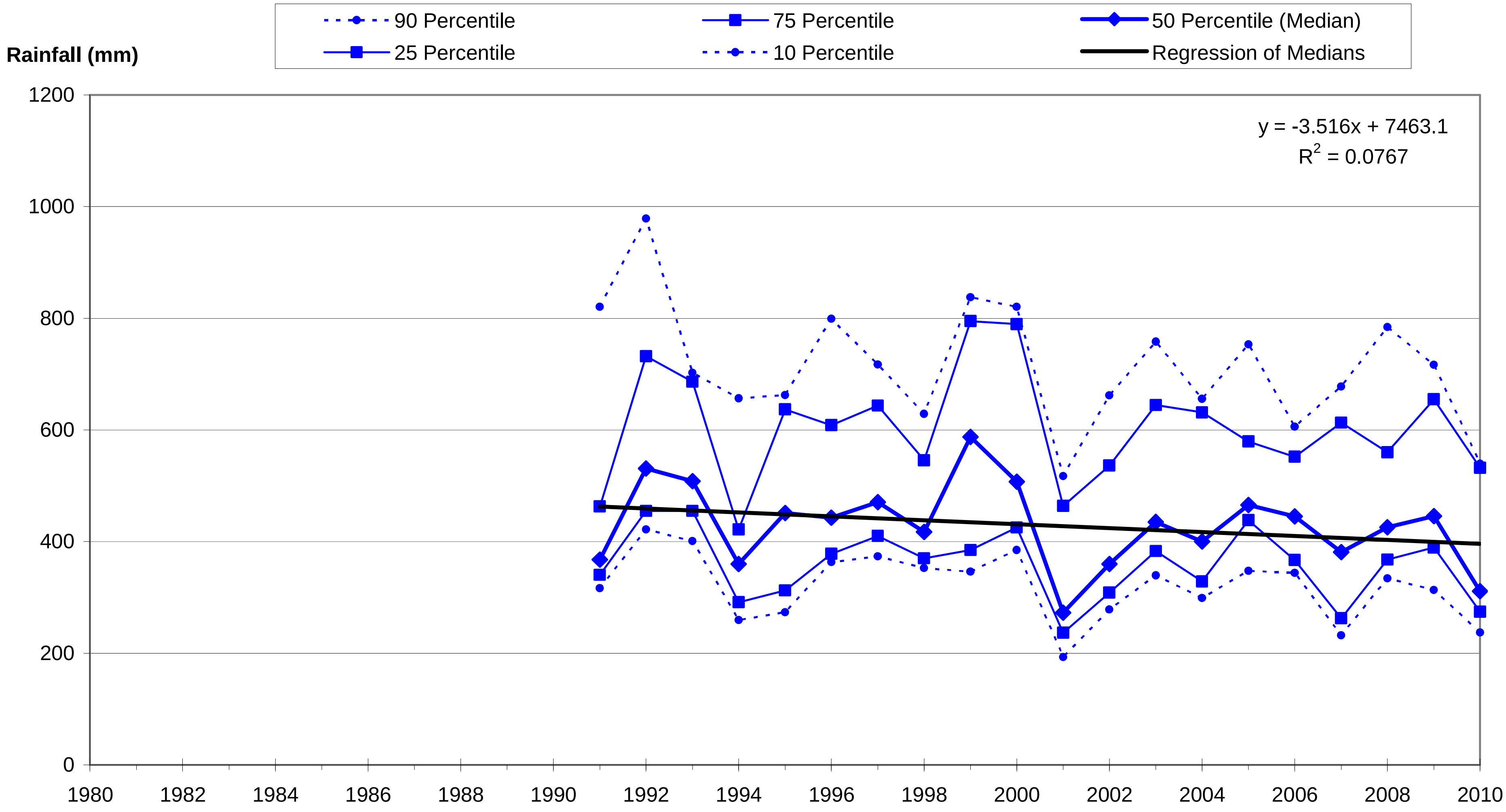
Appendix 15. 1981-2010 '12 Months prior to September' Rainfall Medians, Percentiles and Regression of Medians (n=21)



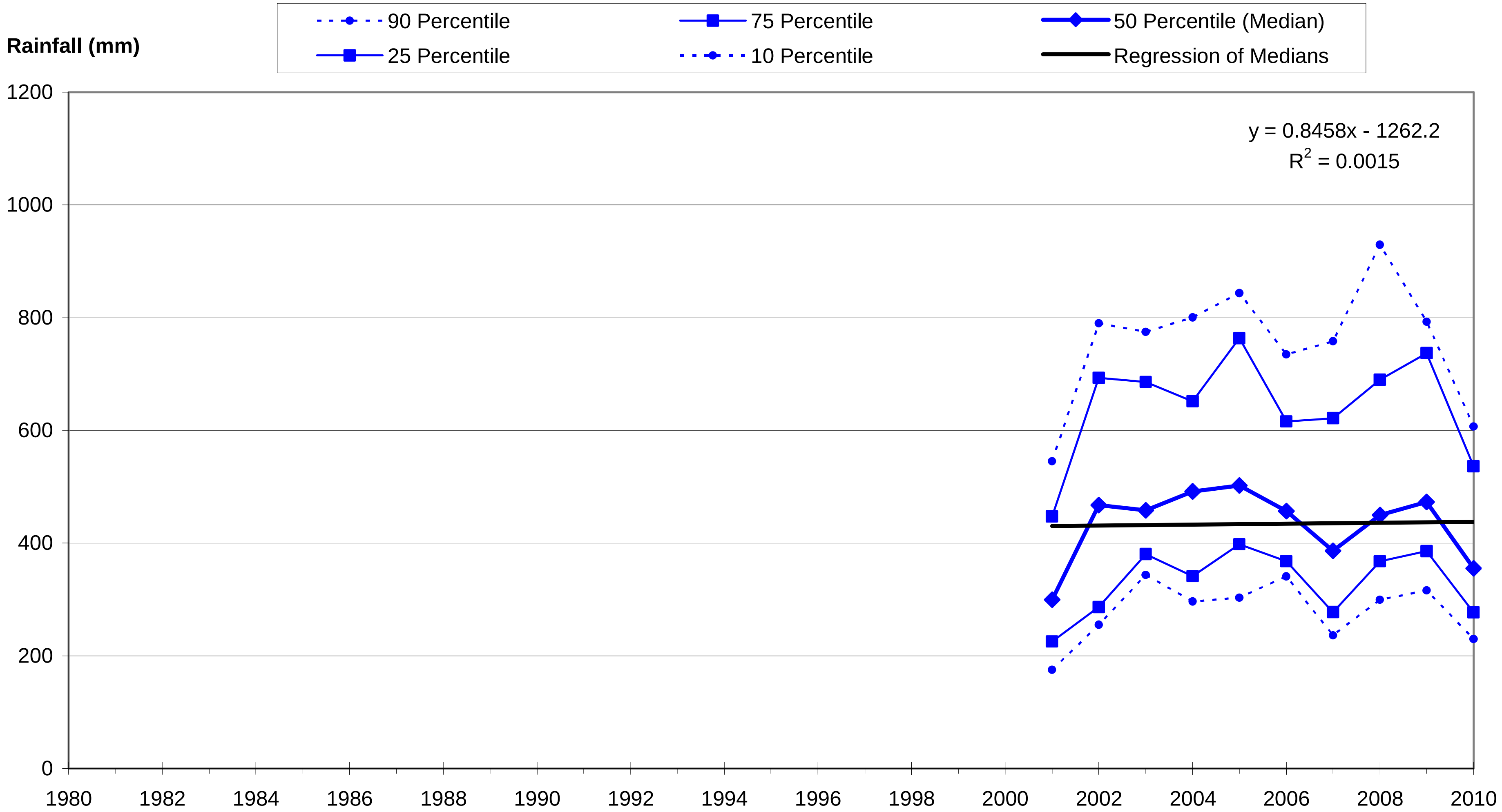
Appendix 16. 1991-2000 '12 Months prior to September' Rainfall Medians, Percentiles and Regressions of Medians (n=28)



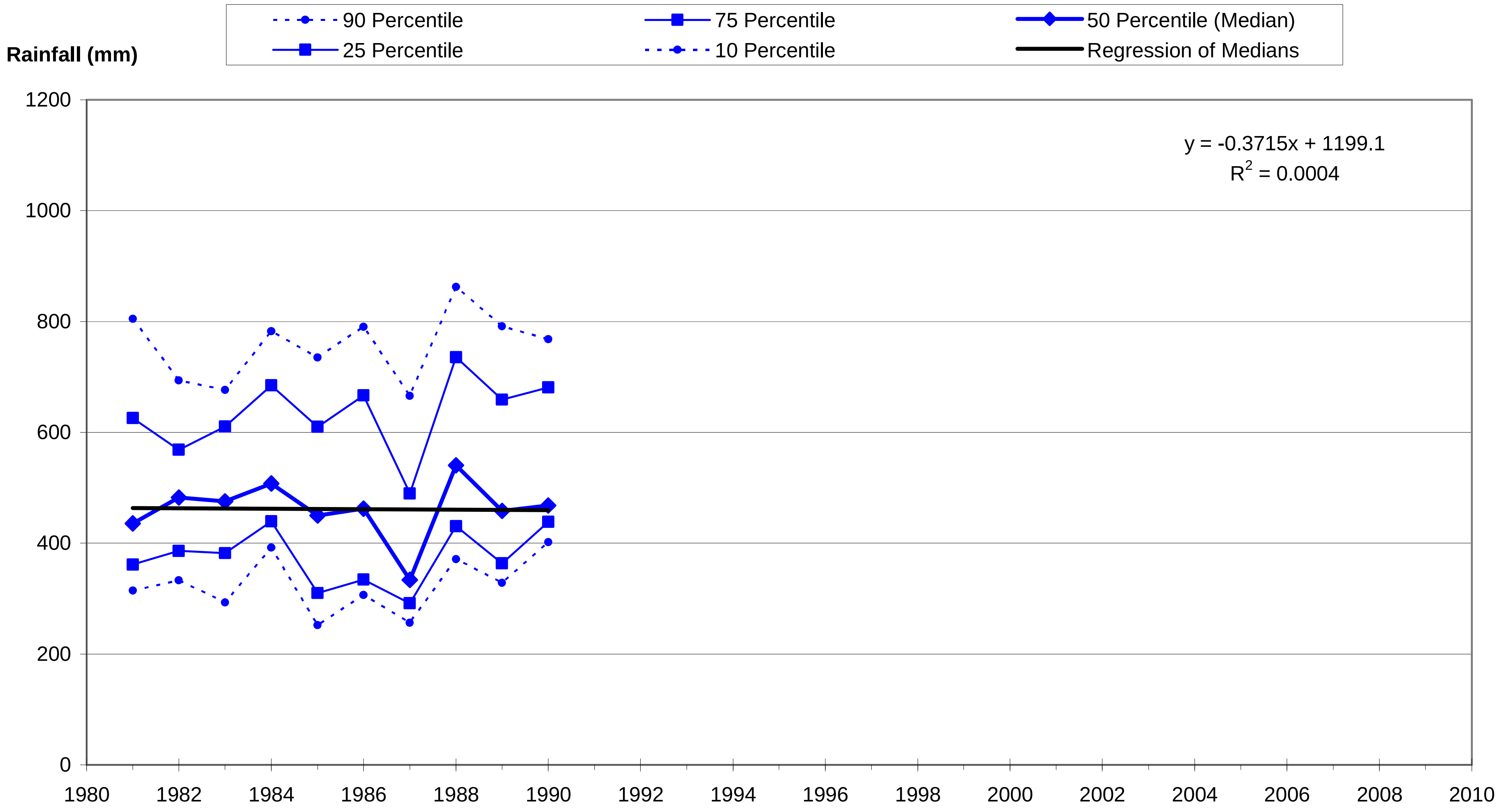
Appendix 17. 1991-2010 '12 Months prior to September' Rainfall Medians, Percentiles and Regression of Medians (n=27)



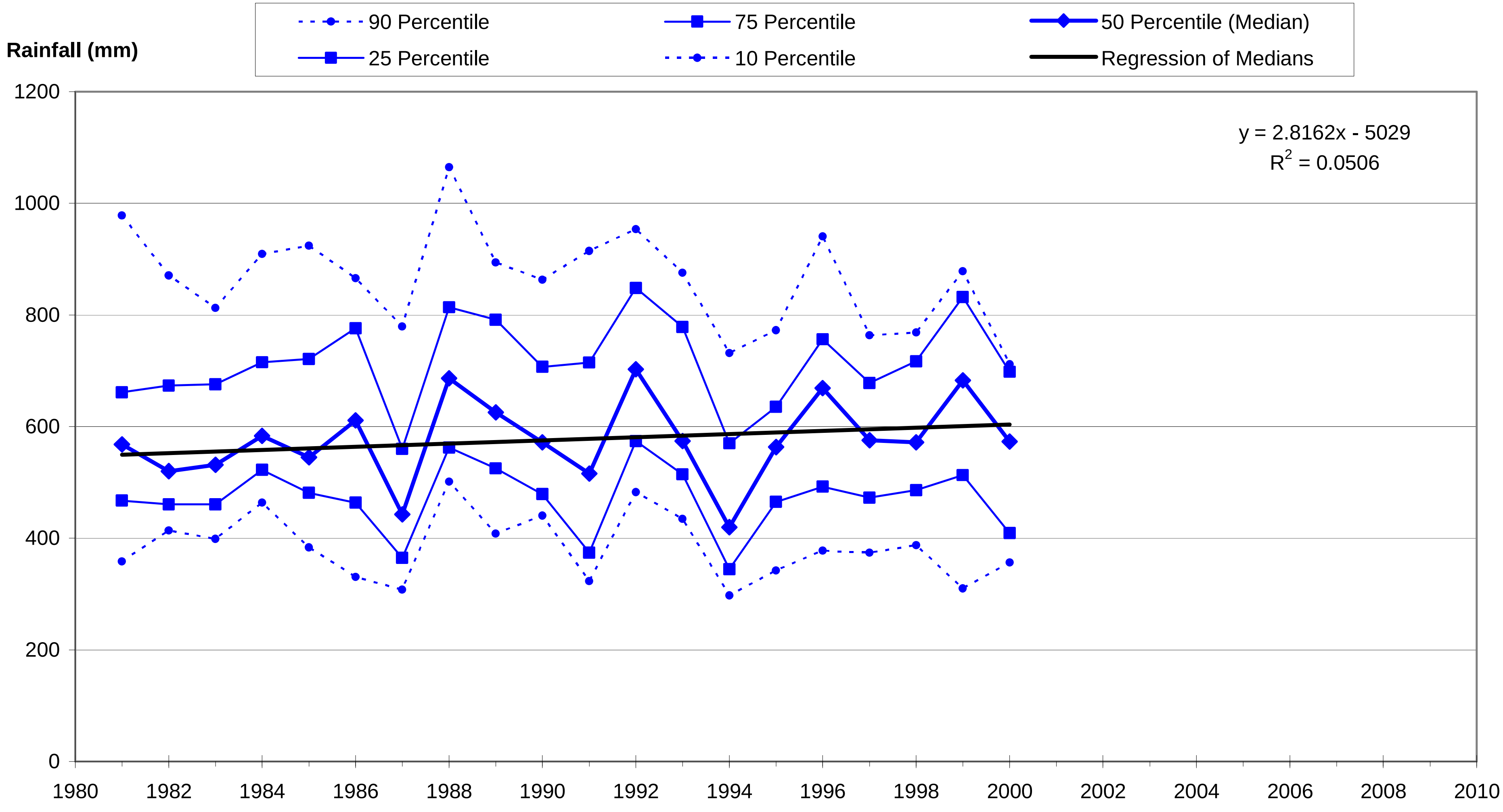
Appendix 18. 2001-2010 '12 Months prior to September' Rainfall Medians, Percentiles and Regression of Medians (n=90)



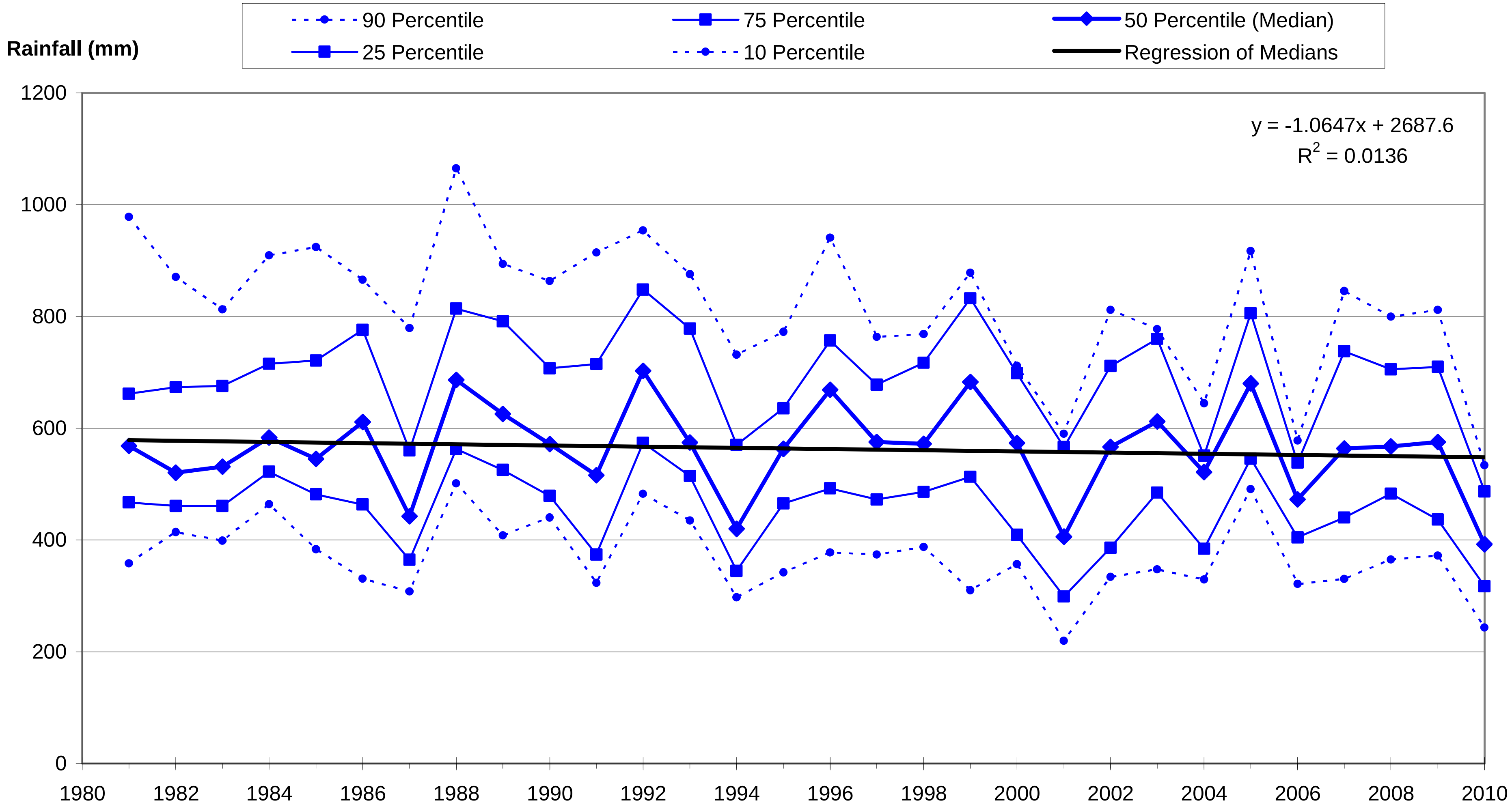
Appendix 19. 1981-1990 '12 Months prior to November' Rainfall Medians, Percentiles and Regression of Medians (n=69)



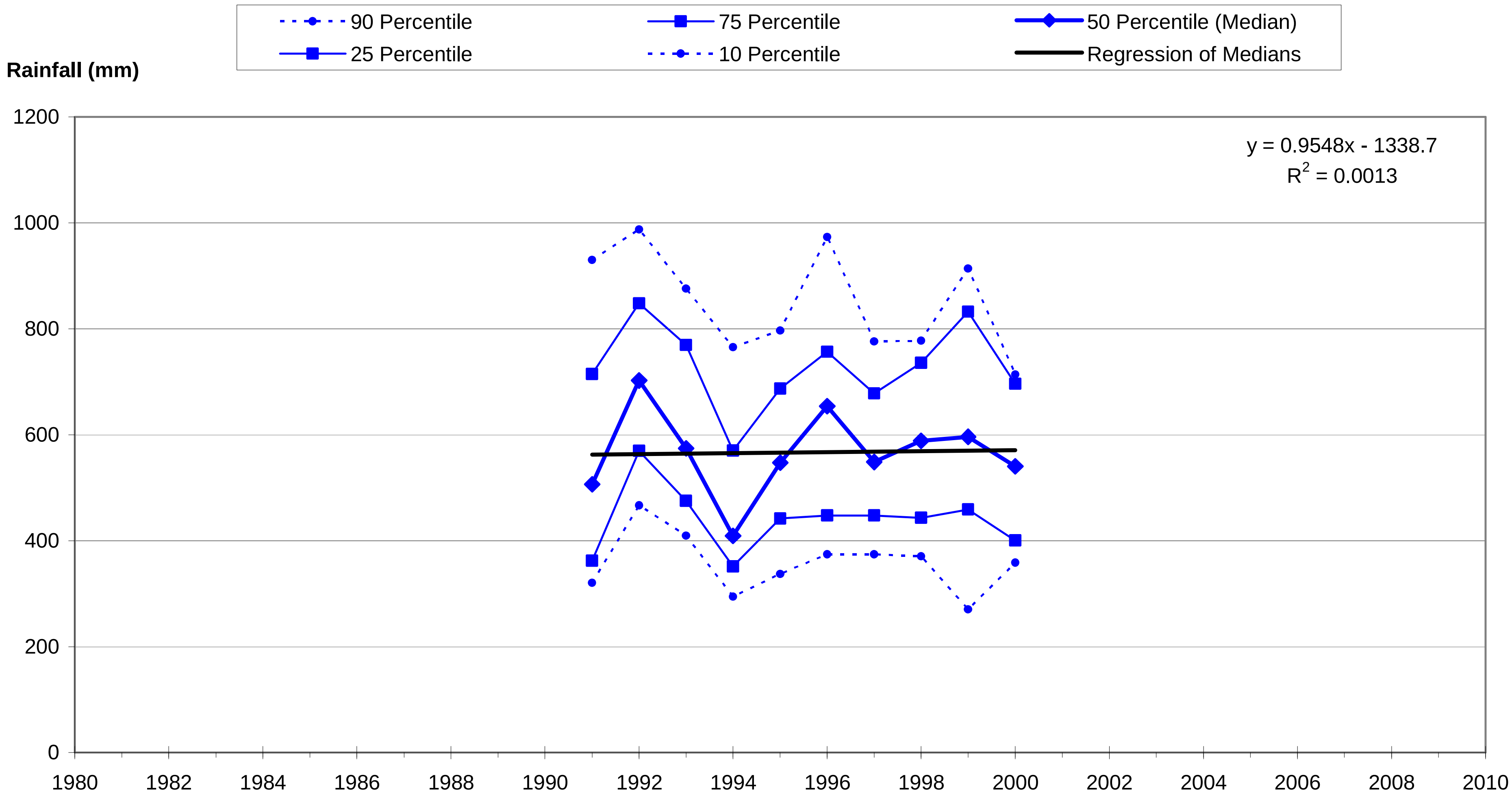
Appendix 20. 1981-2000 '12 Months prior to November' Rainfall Medians, Percentiles and Regression of Medians (n=28)



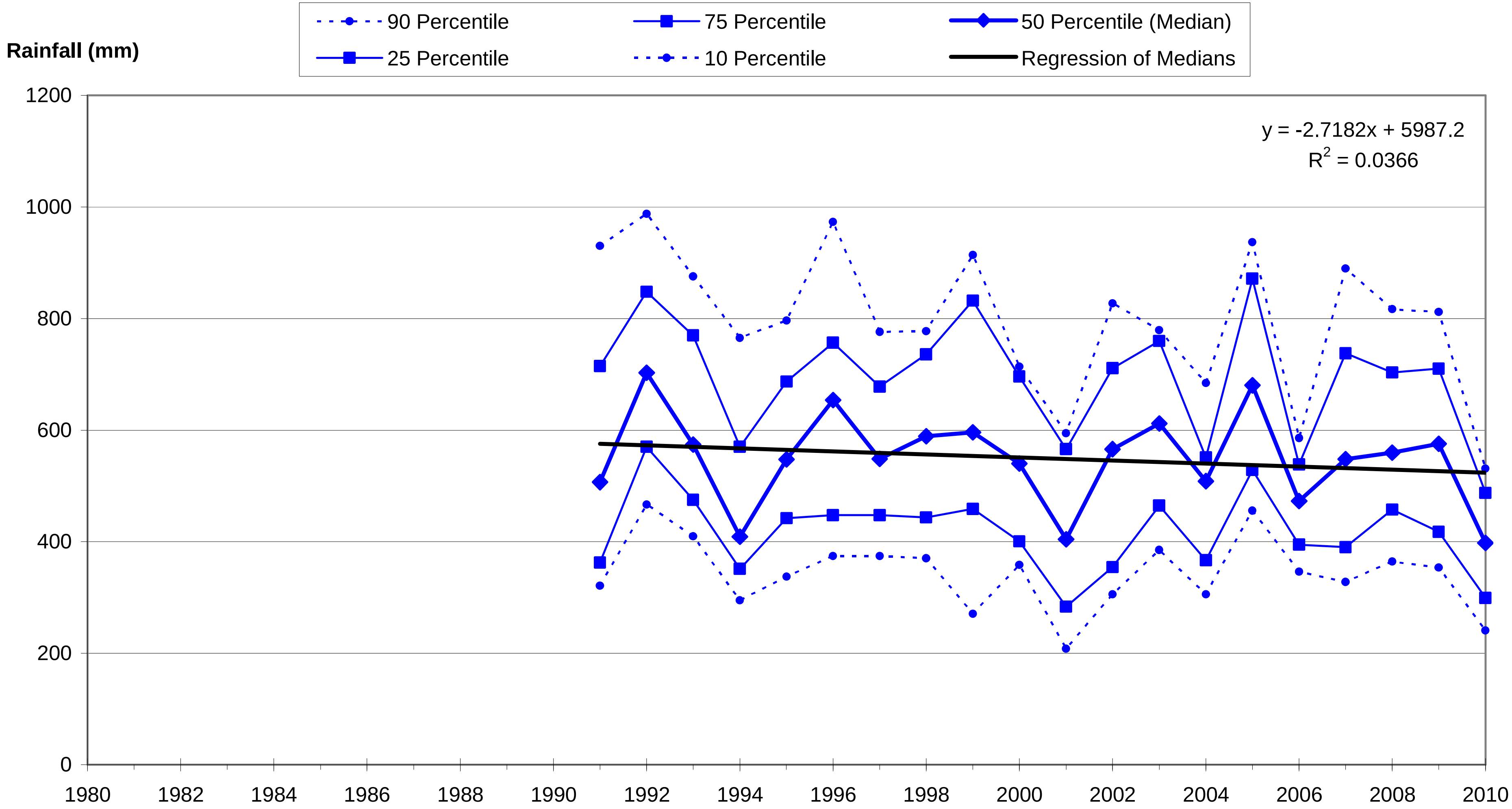
Appendix 21. 1981-2010 '12 Months prior to November' Rainfall Medians, Percentiles and Regression of Medians (n=28)



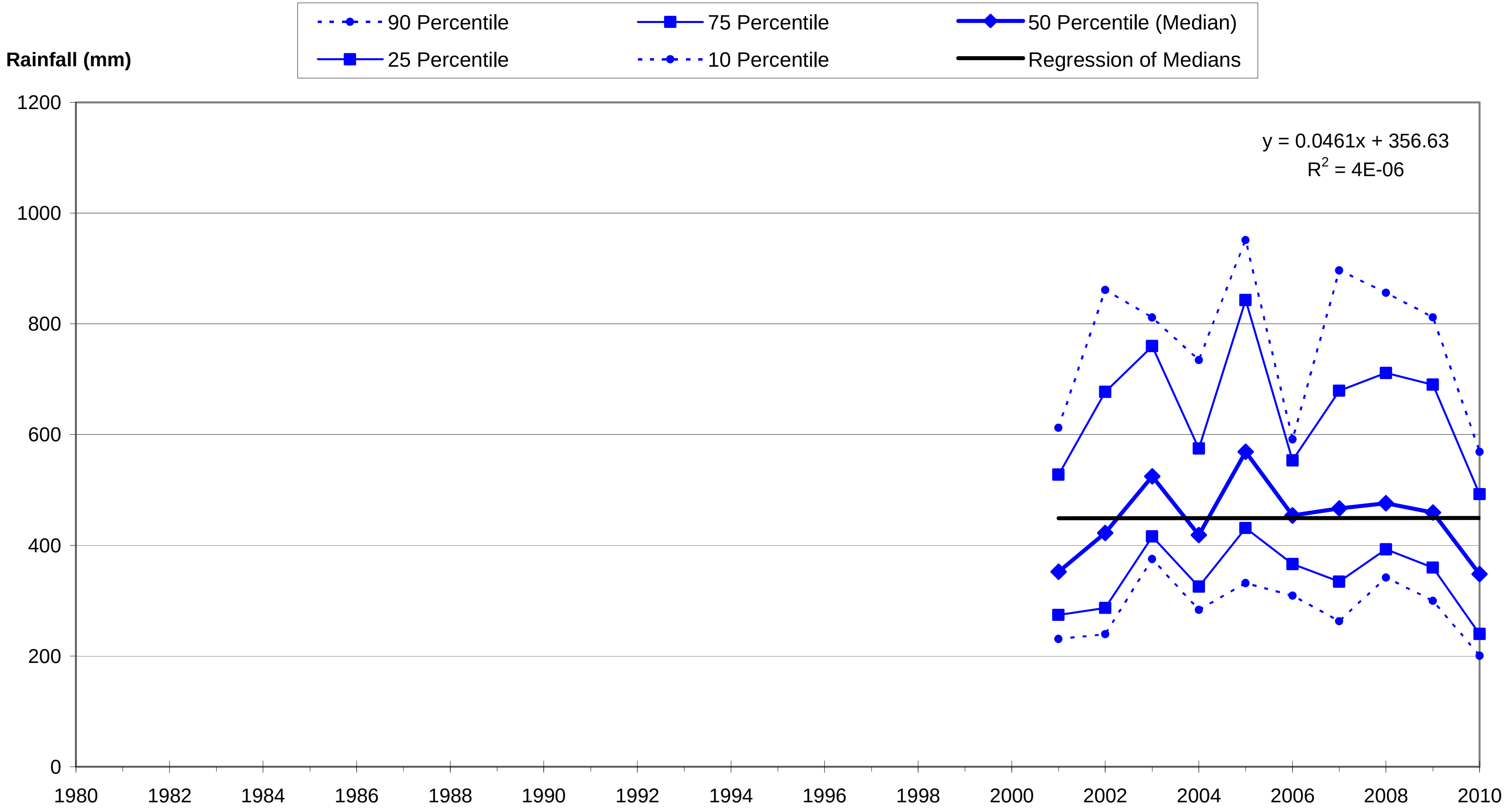
Appendix 22. 1991-2000 '12 Months prior to November' Rainfall Medians, Percentiles and Regression of Medians (n=36)



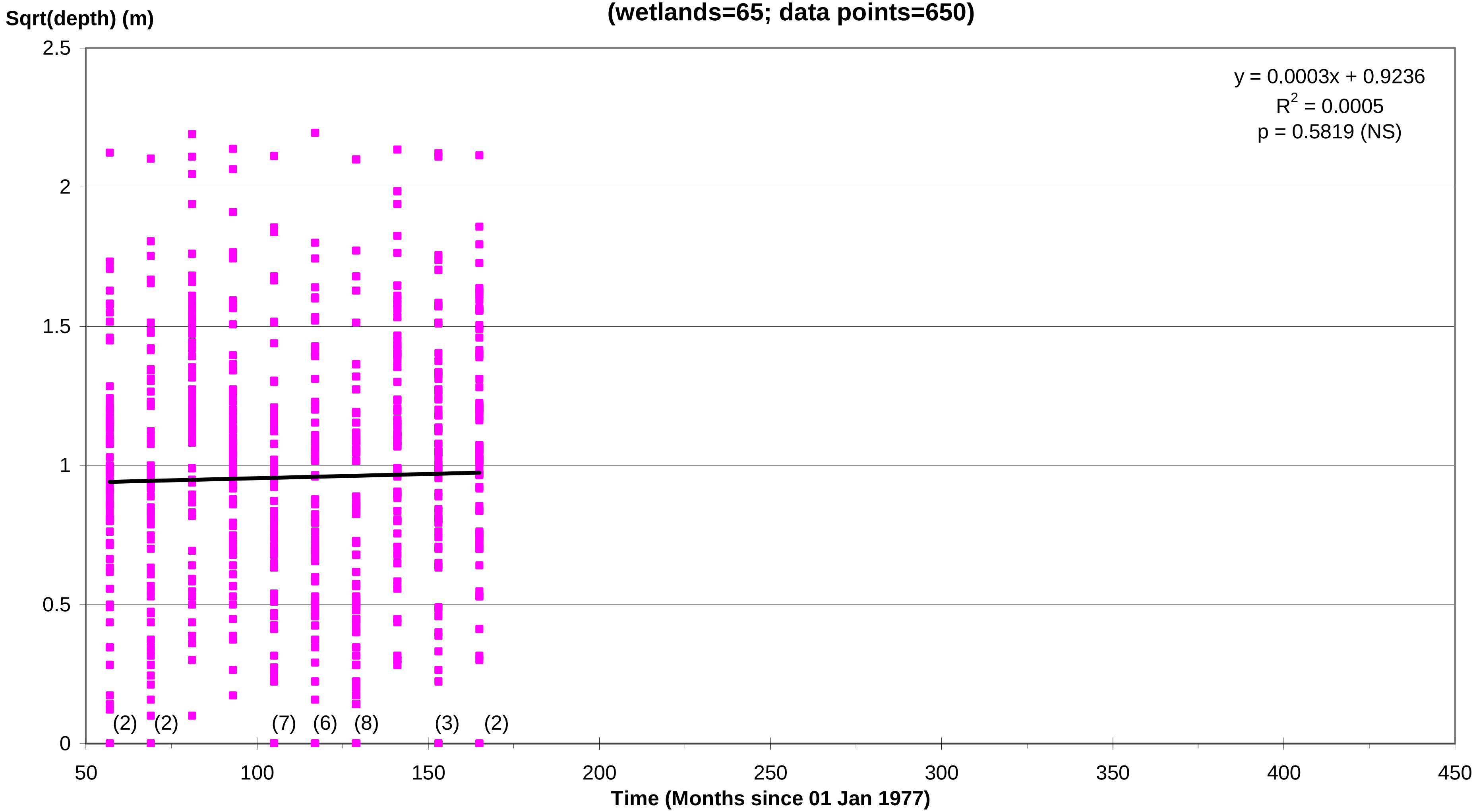
Appendix 23. 1991-2010 '12 Months prior to November' Rainfall Medians, Percentiles and Regression of Medians (n=36)



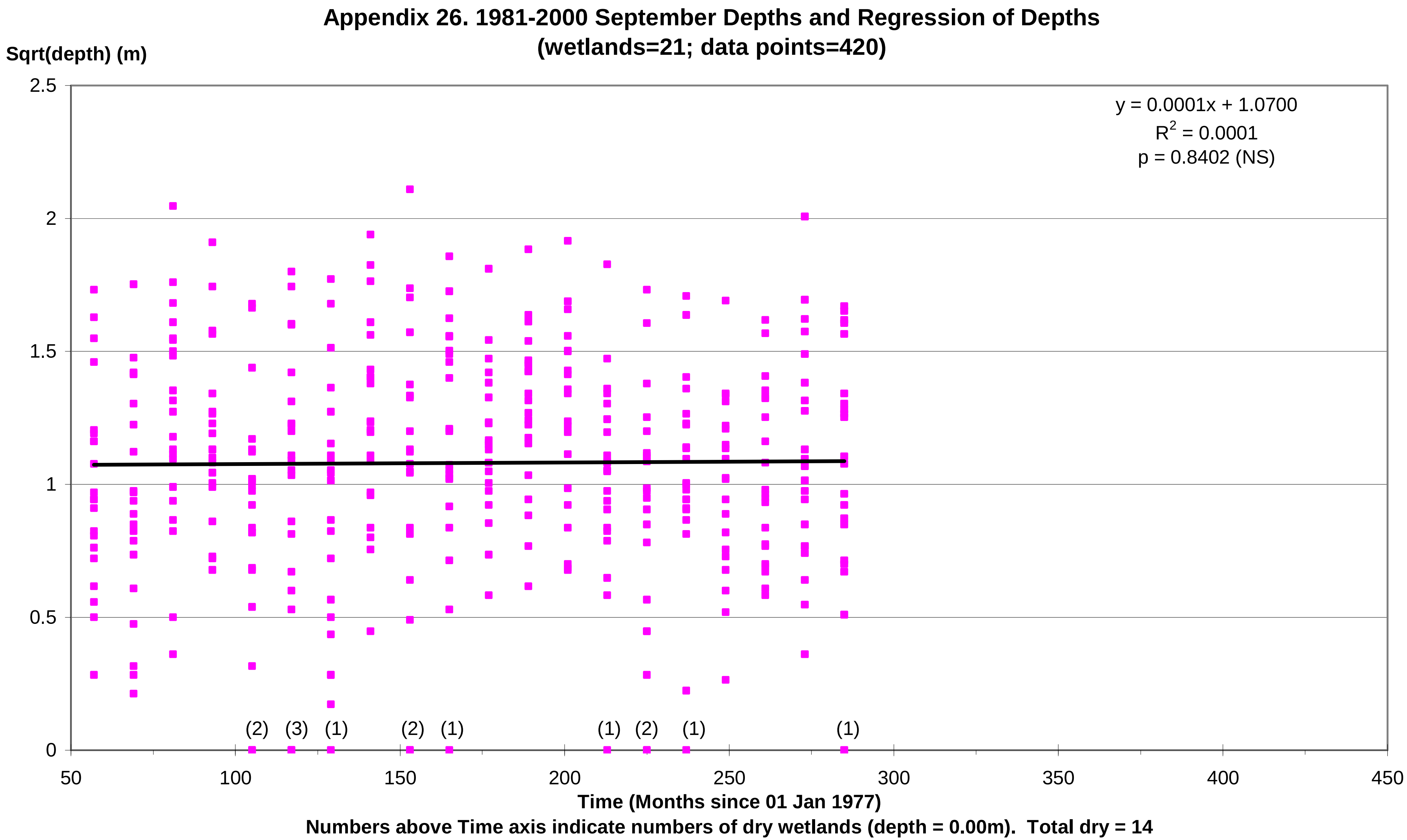
Appendix 24. 2001-2010 '12 Months prior to November' Rainfall Medians, Percentiles and Regression of Medians (n=94)

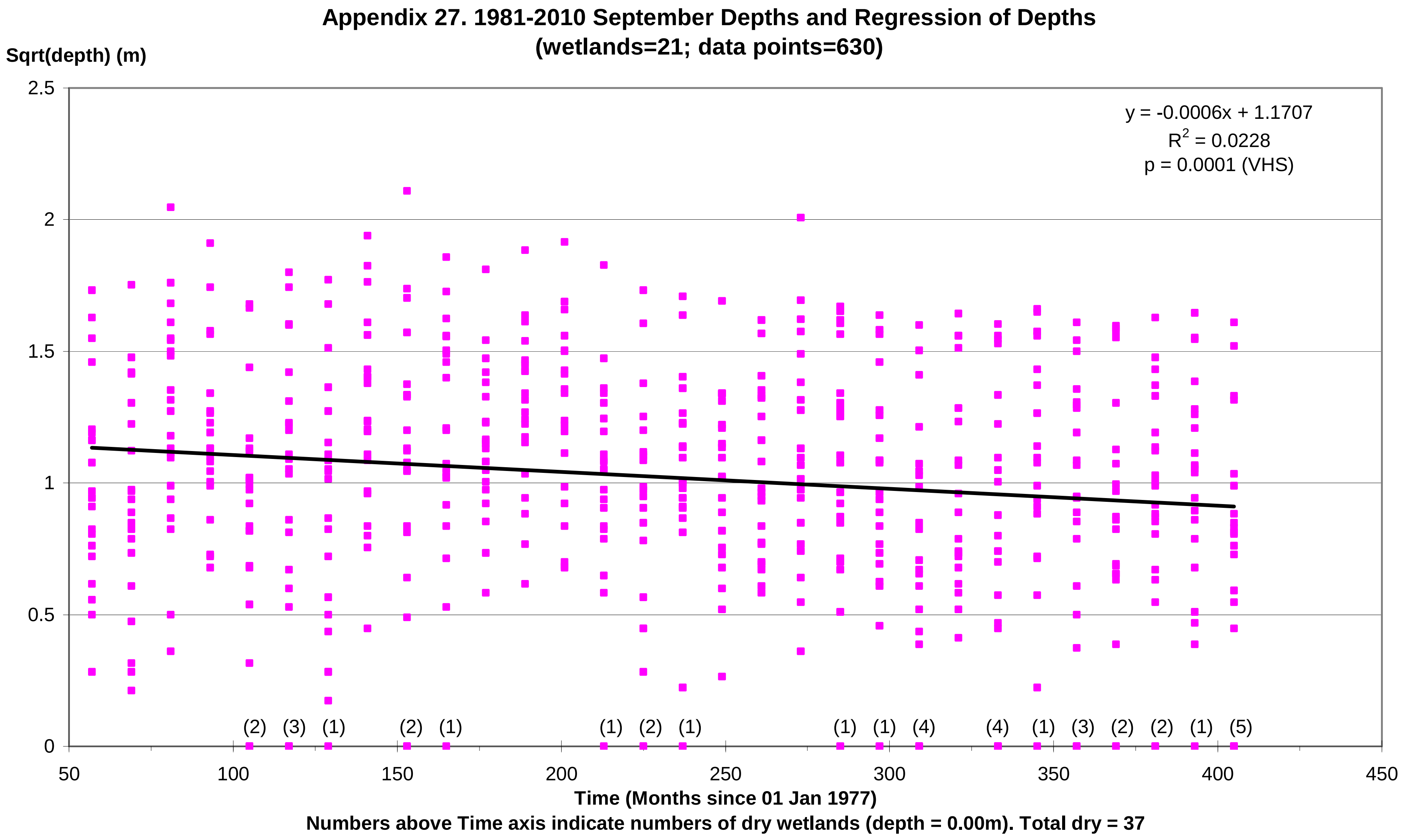


Appendix 25. 1981-1990 September Depths and Regression of Depths (wetlands=65; data points=650)

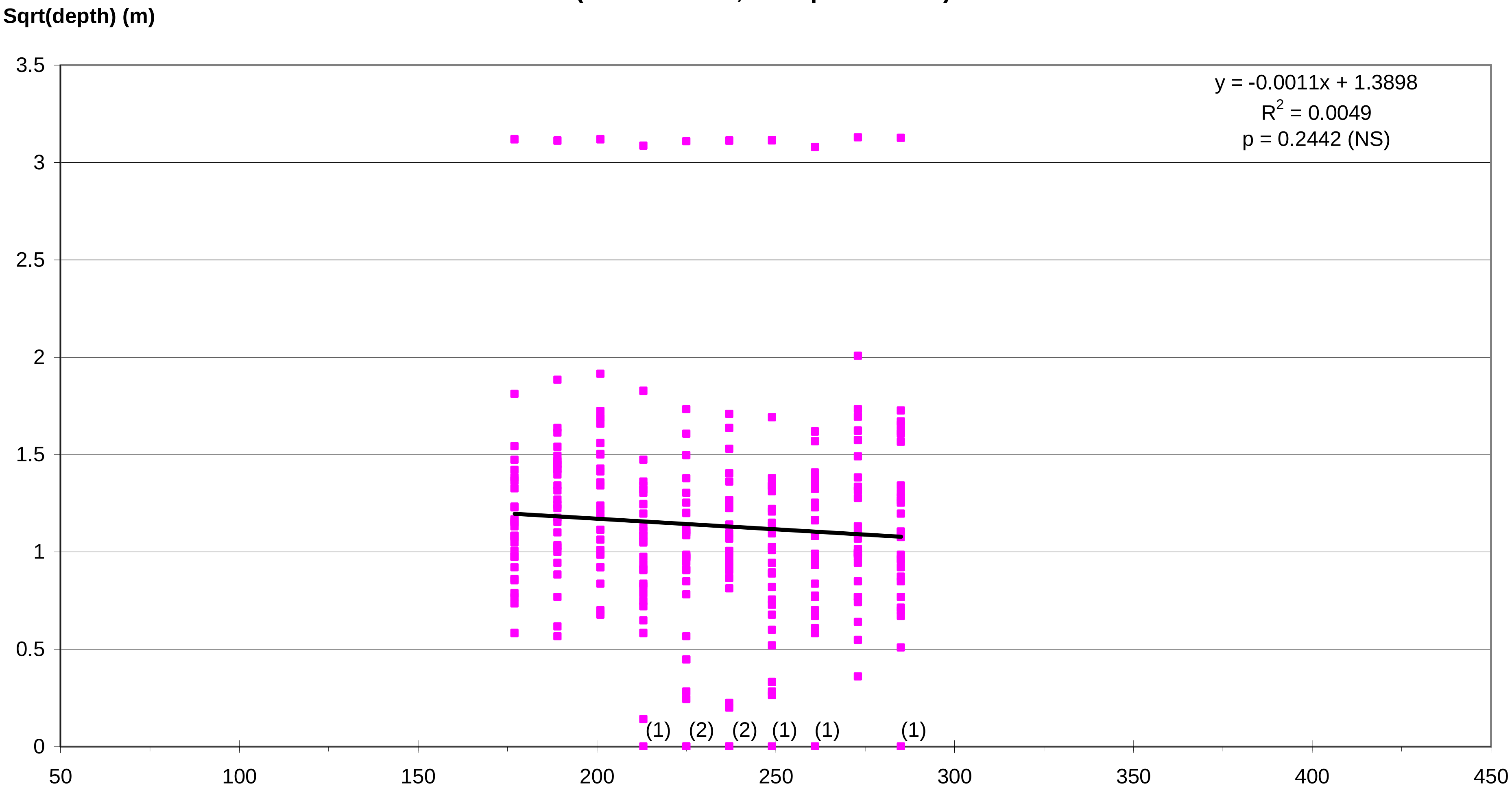


Numbers above Time axis indicate numbers of dry wetlands (depth = 0.00m). Total dry = 30


Appendix 26. 1981-2000 September Depths and Regression of Depths
(wetlands=21; data points=420)
Sqrt(depth) (m)
y = 0.0001x + 1.0700
R^2 = 0.0001
p = 0.8402 (NS)
2.5
2
1.5
1
0.5
0
(2) (3) (1) (2) (1) (1) (2) (1) (1)
50
100
150
200
250
300
350
400
450
Time (Months since 01 Jan 1977)
Numbers above Time axis indicate numbers of dry wetlands (depth = 0.00m). Total dry = 14


Appendix 27. 1981-2010 September Depths and Regression of Depths
(wetlands=21; data points=630)
Sqrt(depth) (m)
2.5
2
1.5
1
0.5
0
y = -0.0006x + 1.1707
R2 = 0.0228
p = 0.0001 (VHS)
(2) (3) (1) (2) (1) (1) (2) (1) (1) (1) (4) (4) (1) (3) (2) (2) (1) (5)
50
100
150
200
250
300
350
400
450
Time (Months since 01 Jan 1977)
Numbers above Time axis indicate numbers of dry wetlands (depth = 0.00m). Total dry = 37

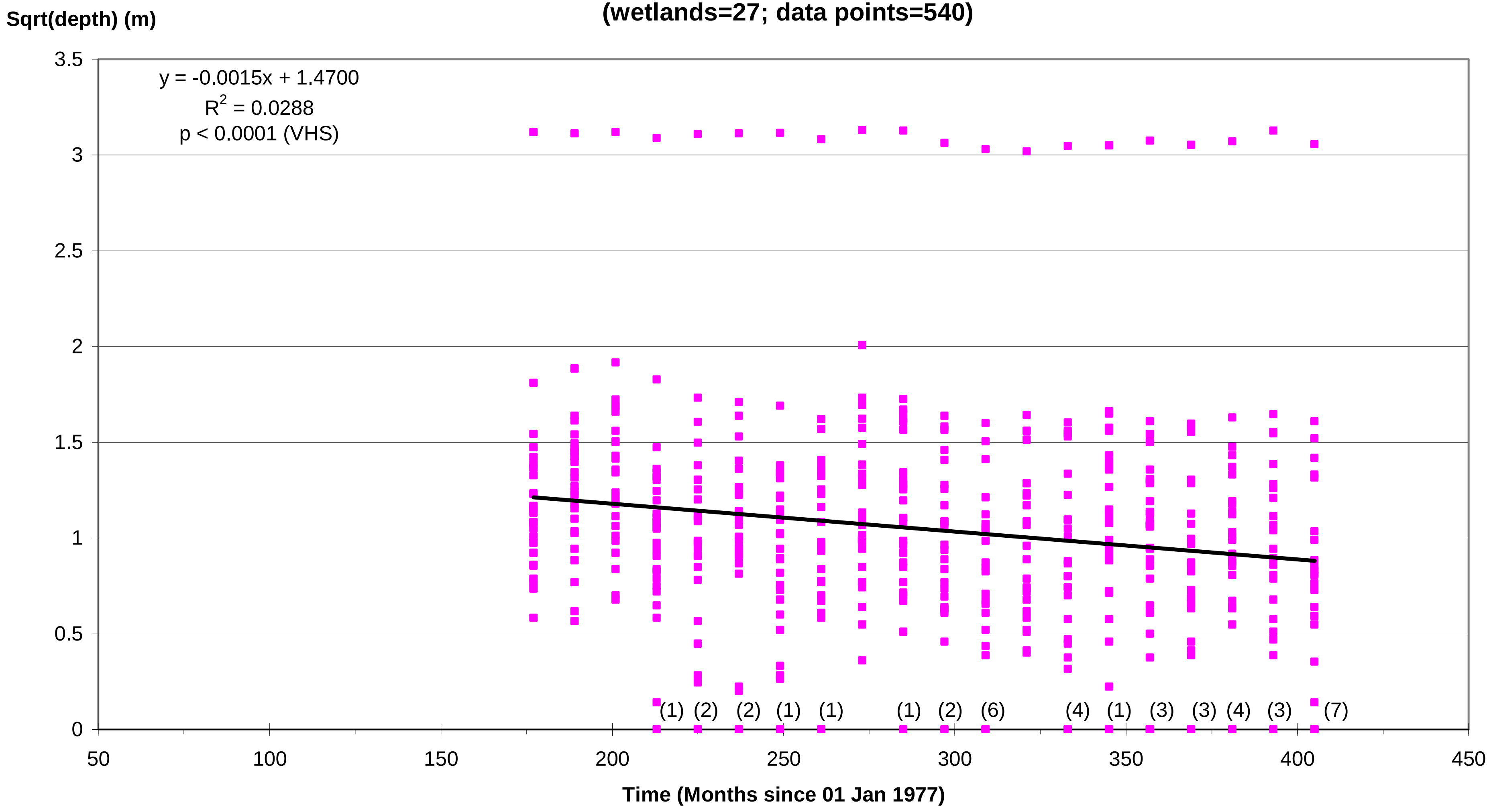
Appendix 28. 1991-2000 September Depths and Regression of Depths (wetlands=28; data points=280)



Time (Months since 01 Jan 1977)

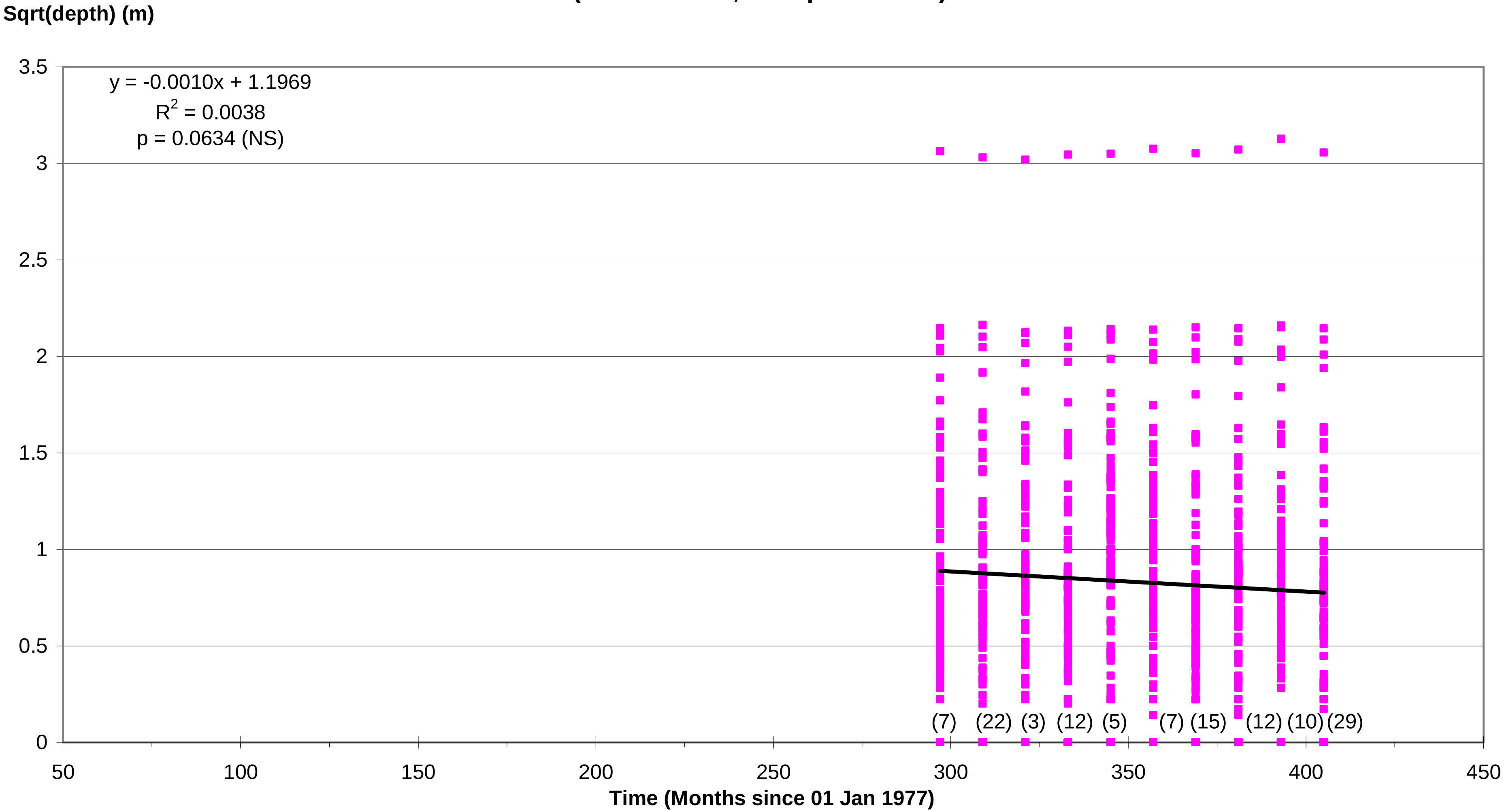
Numbers above Time axis indicate numbers of dry wetlands (depth = 0.00m). Total dry = 8

Appendix 29. 1991-2010 September Depths and Regression of Depths (wetlands=27; data points=540)



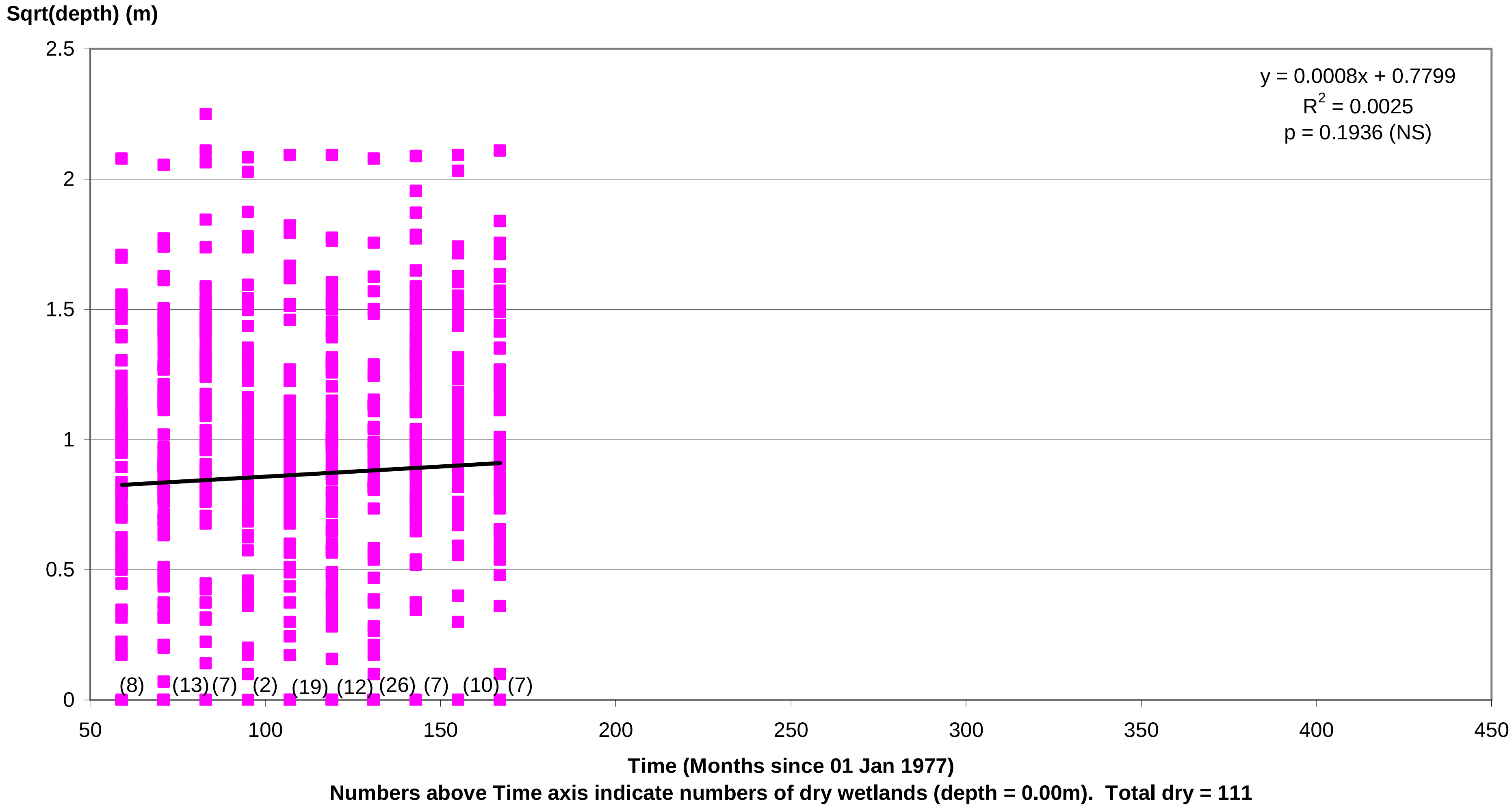
Numbers above Time axis indicate numbers of dry wetlands (depth = 0.00m). Total dry = 41

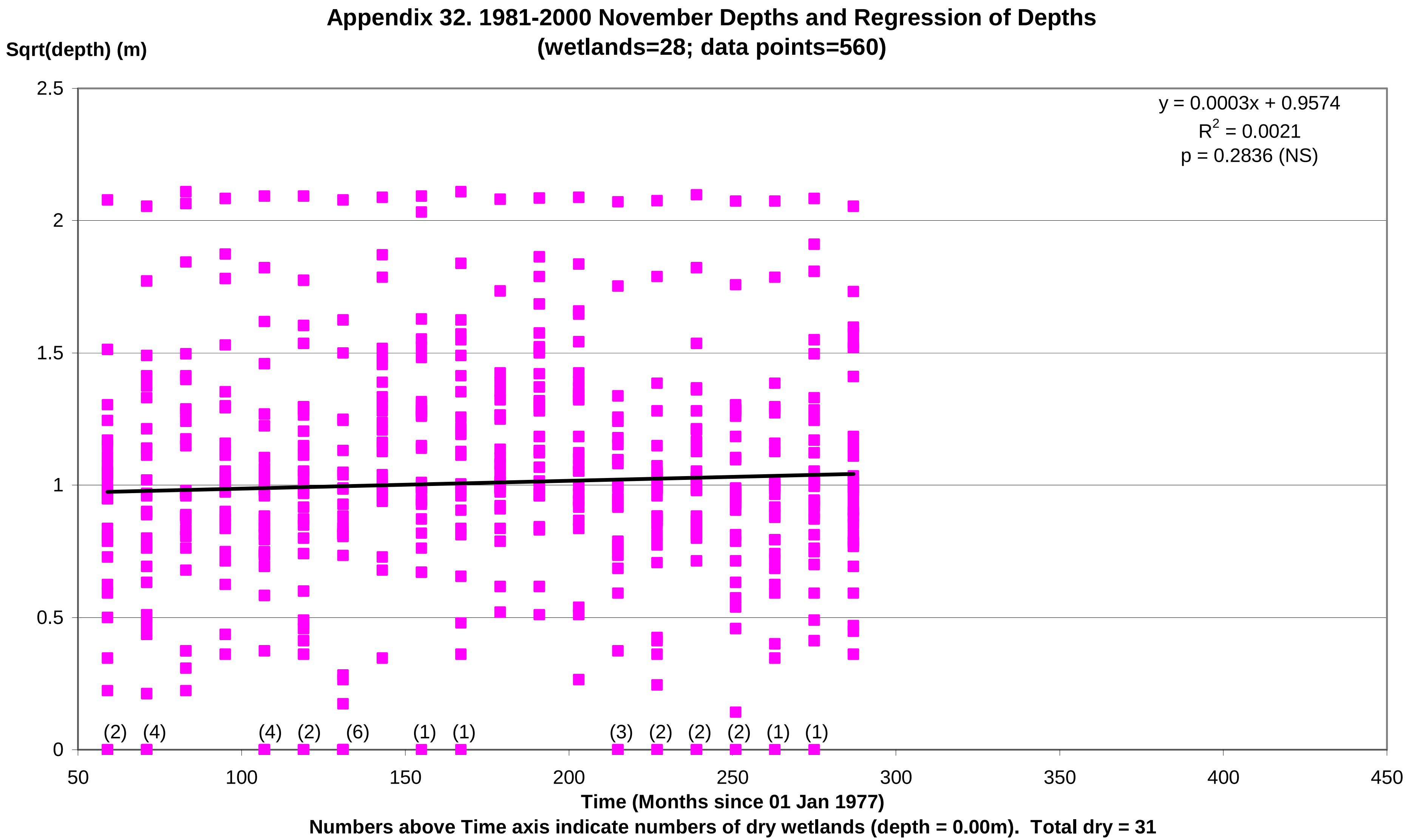
Appendix 30. 2001-2010 September Depths and Regression of Depths (wetlands=90; data points=900)



Numbers above Time axis indicates numbers of dry wetlands (depth = 0.00m). Total dry = 122

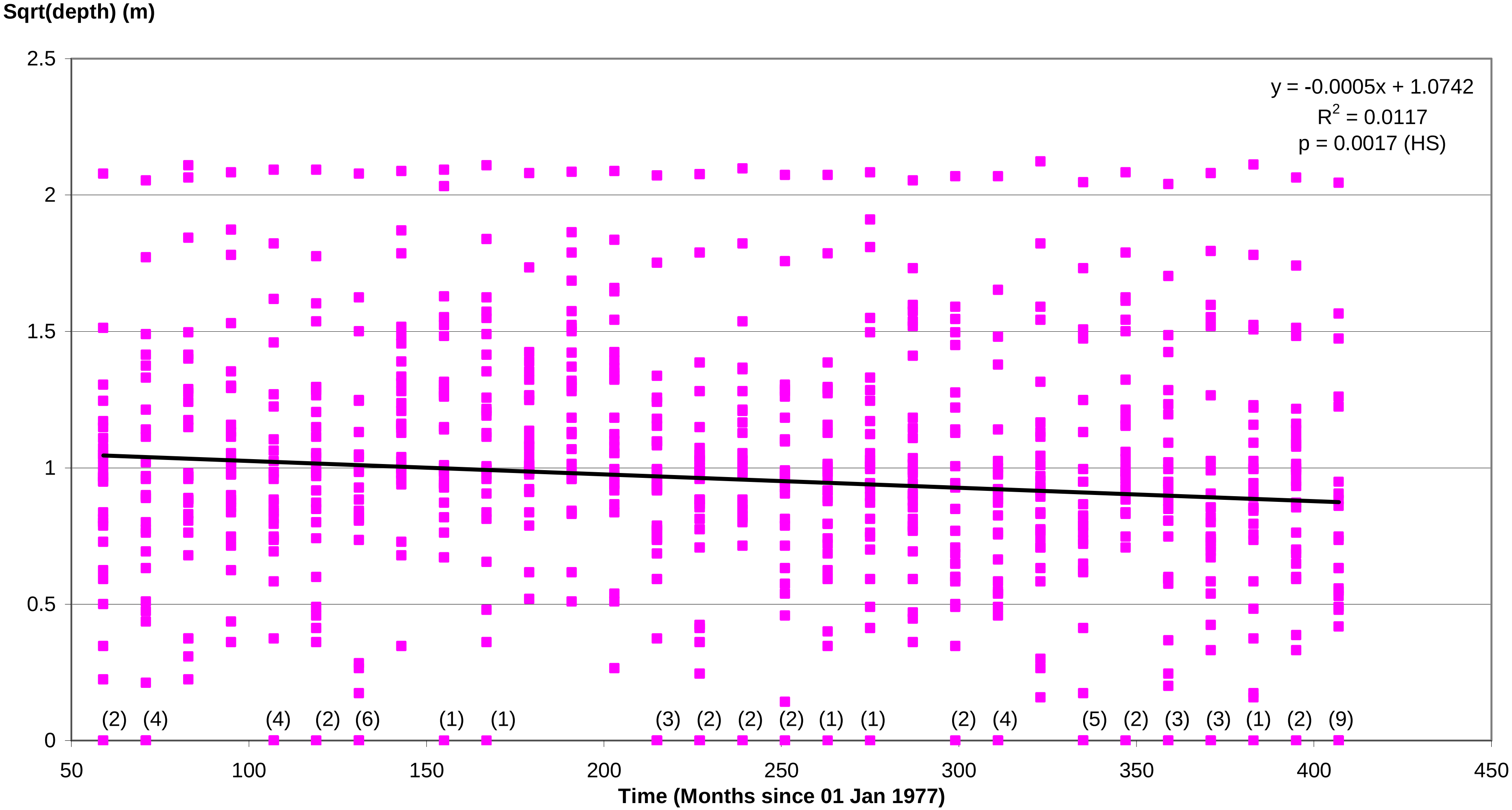
Appendix 31. 1981-1990 November Depths and Regression of Depths (wetlands=69; data points=690)





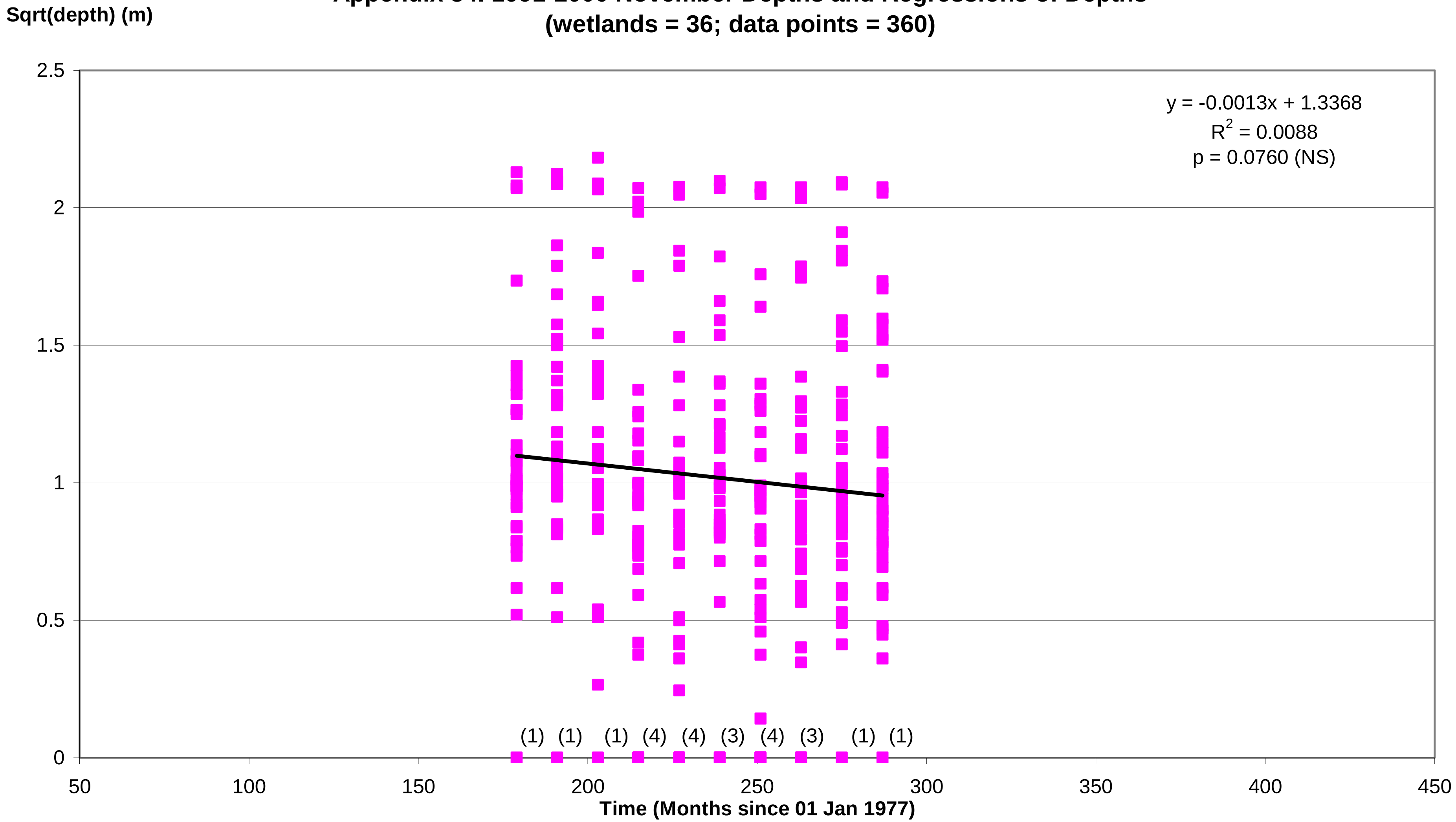
Appendix 32. 1981-2000 November Depths and Regression of Depths
(wetlands=28; data points=560)
Sqrt(depth) (m)
y = 0.0003x + 0.9574
$R^2 = 0.0021$
p = 0.2836 (NS)
2.5
2
1.5
1
0.5
0
(2) (4) (4) (2) (6) (1) (1) (3) (2) (2) (2) (1) (1)
50 100 150 200 250 300 350 400 450
Time (Months since 01 Jan 1977)
Numbers above Time axis indicate numbers of dry wetlands (depth = 0.00m). Total dry = 31

Appendix 33. 1981-2010 November Depths and Regression of Depths (wetlands=28; data points = 840)



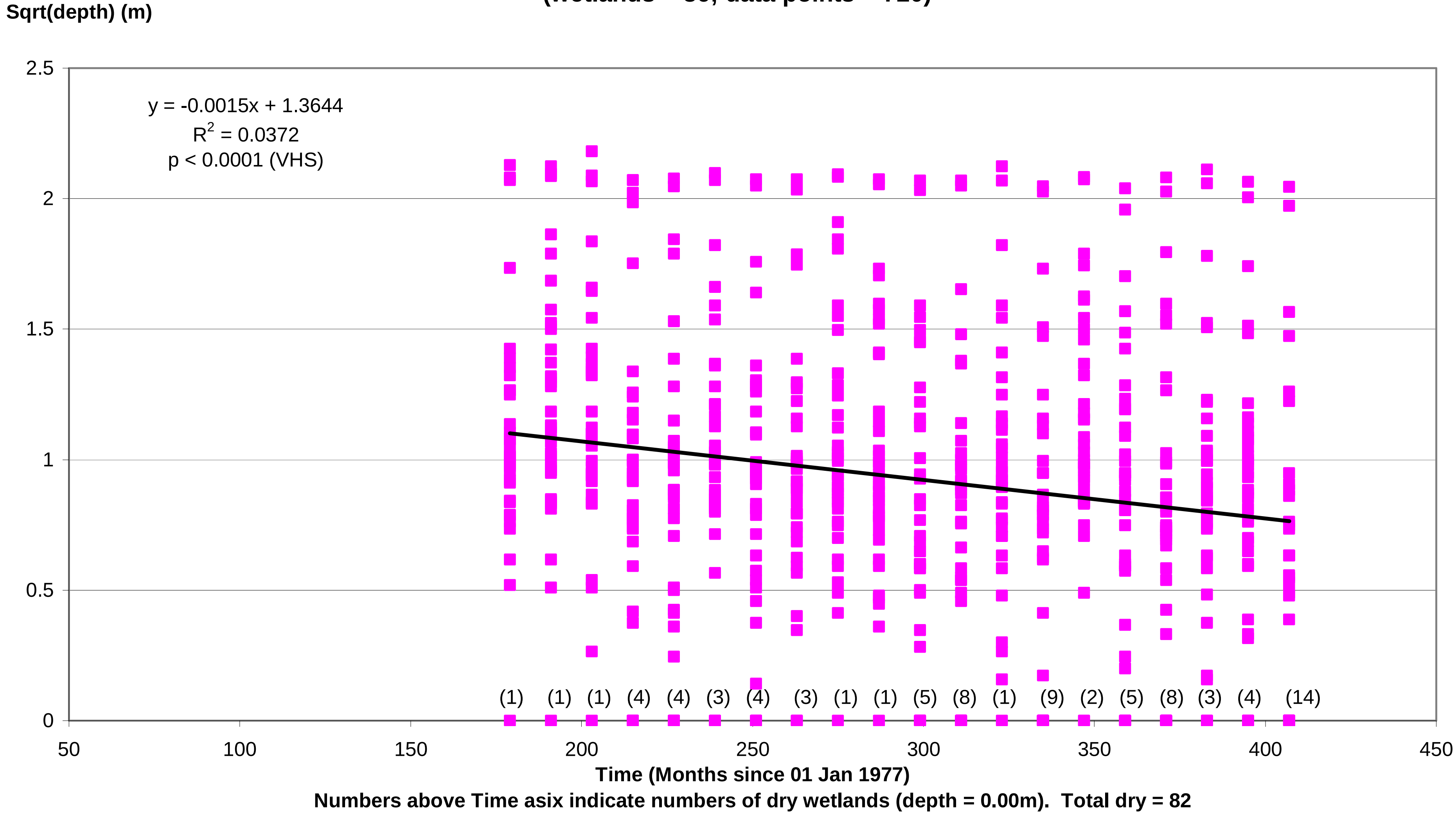
Numbers above Time axis indicate numbers of dry wetlands (depth = 0.00m). Total dry = 62

Appendix 34. 1991-2000 November Depths and Regressions of Depths
(wetlands = 36; data points = 360)

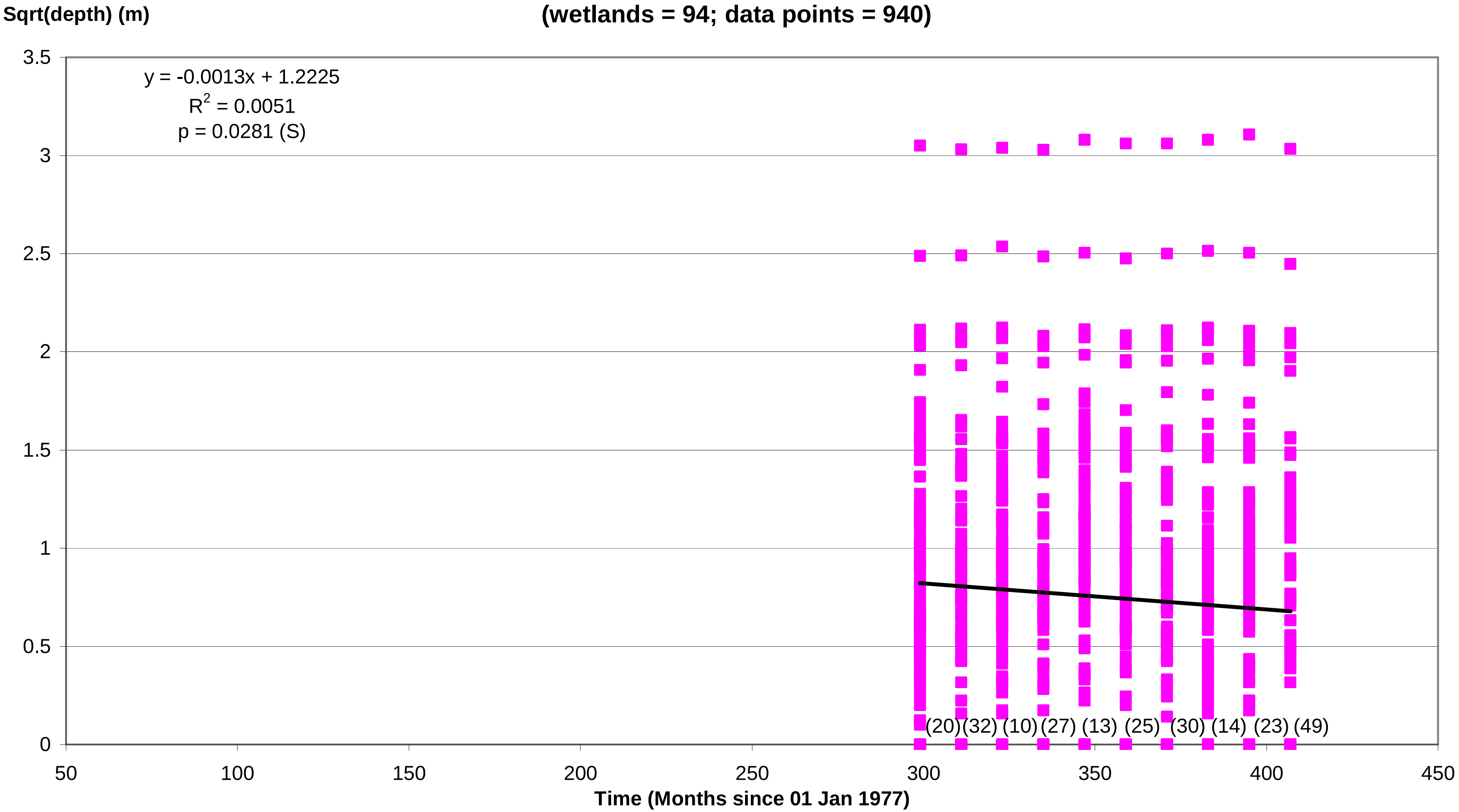


Number above Time axis indicate numbers of dry wetlands (depth = 0.00m). Total dry = 23

Appendix 35. 1991-2010 November Depths and Regression of Depths (wetlands = 36; data points = 720)

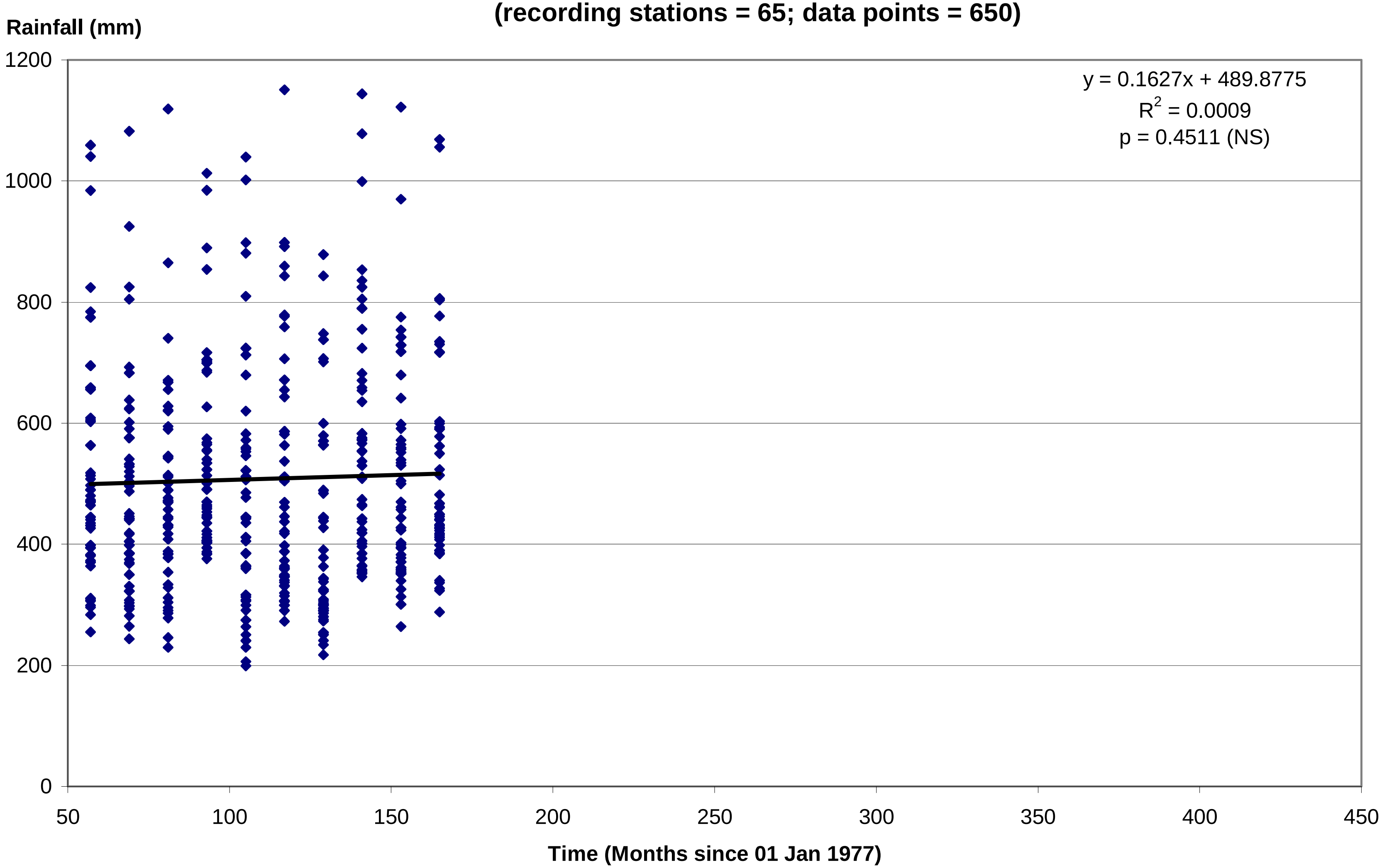


Appendix 36. 2001-2010 November Depths and Regression of Depths (wetlands = 94; data points = 940)

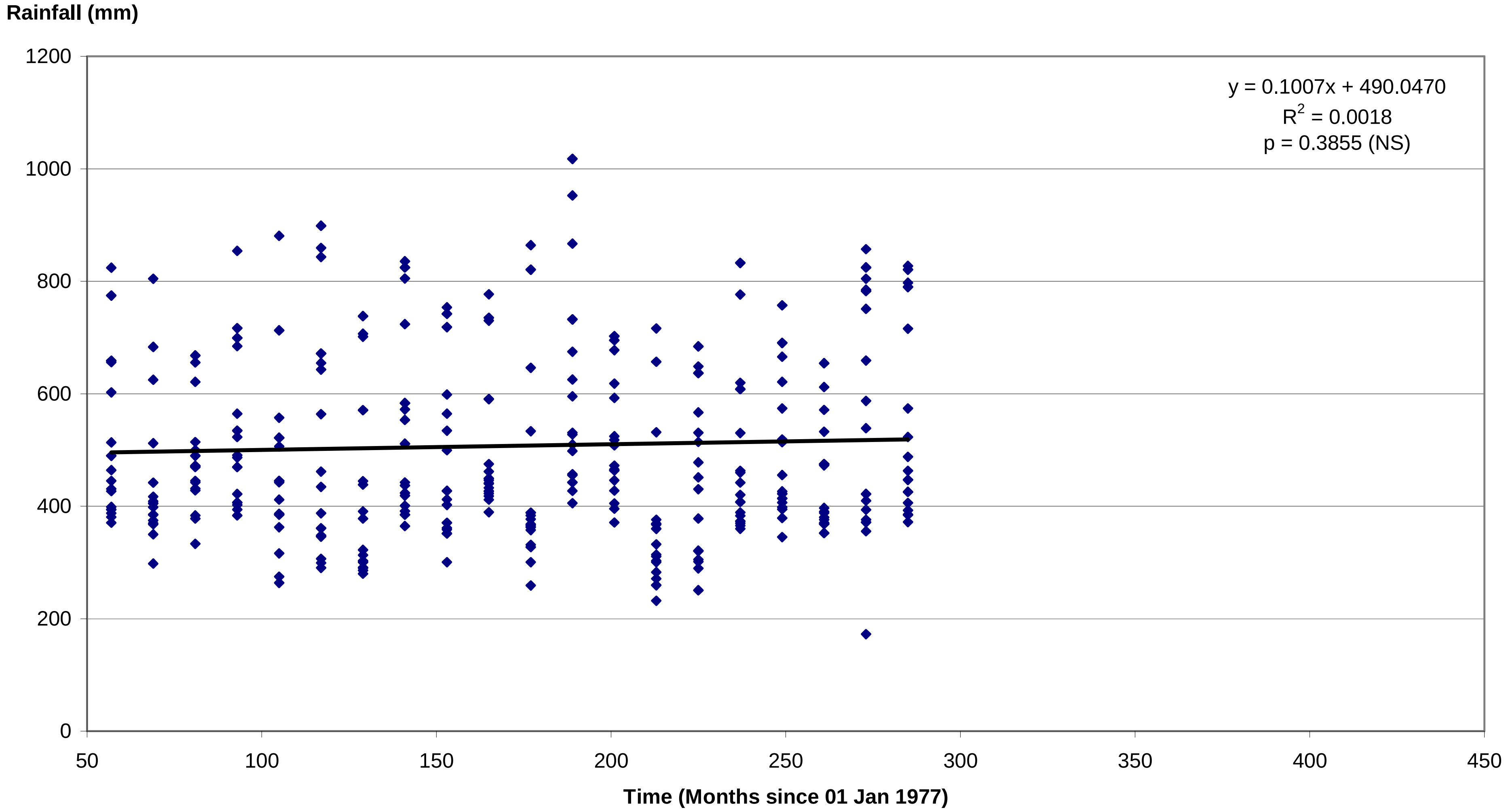


Number above Time axis indicate numbers of dry wetlands (depth=0.00m). Total dry = 243

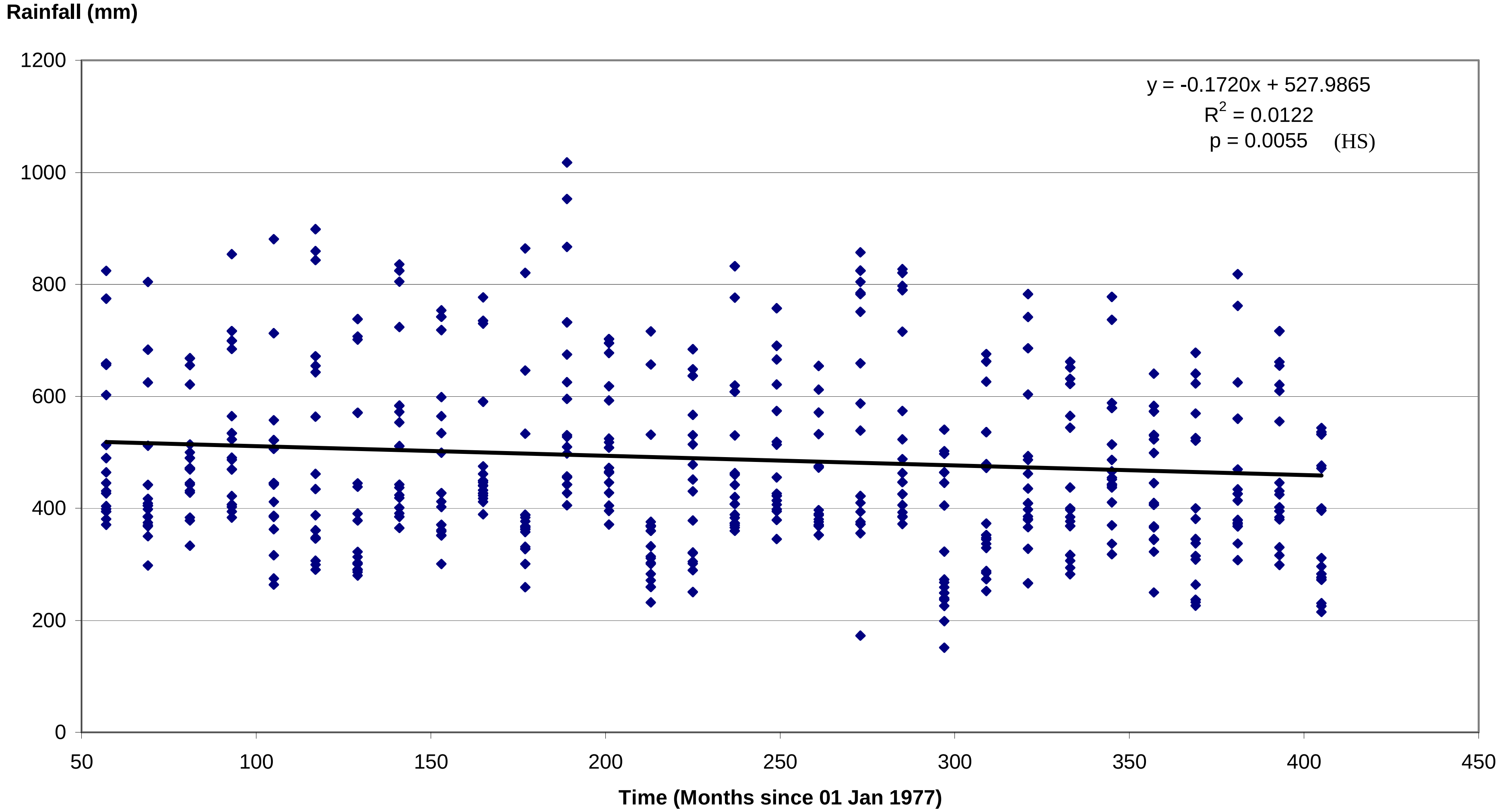
Appendix 37. 1981-1990 '12 months prior to September' Rainfalls and Regression of Rainfalls (recording stations = 65; data points = 650)



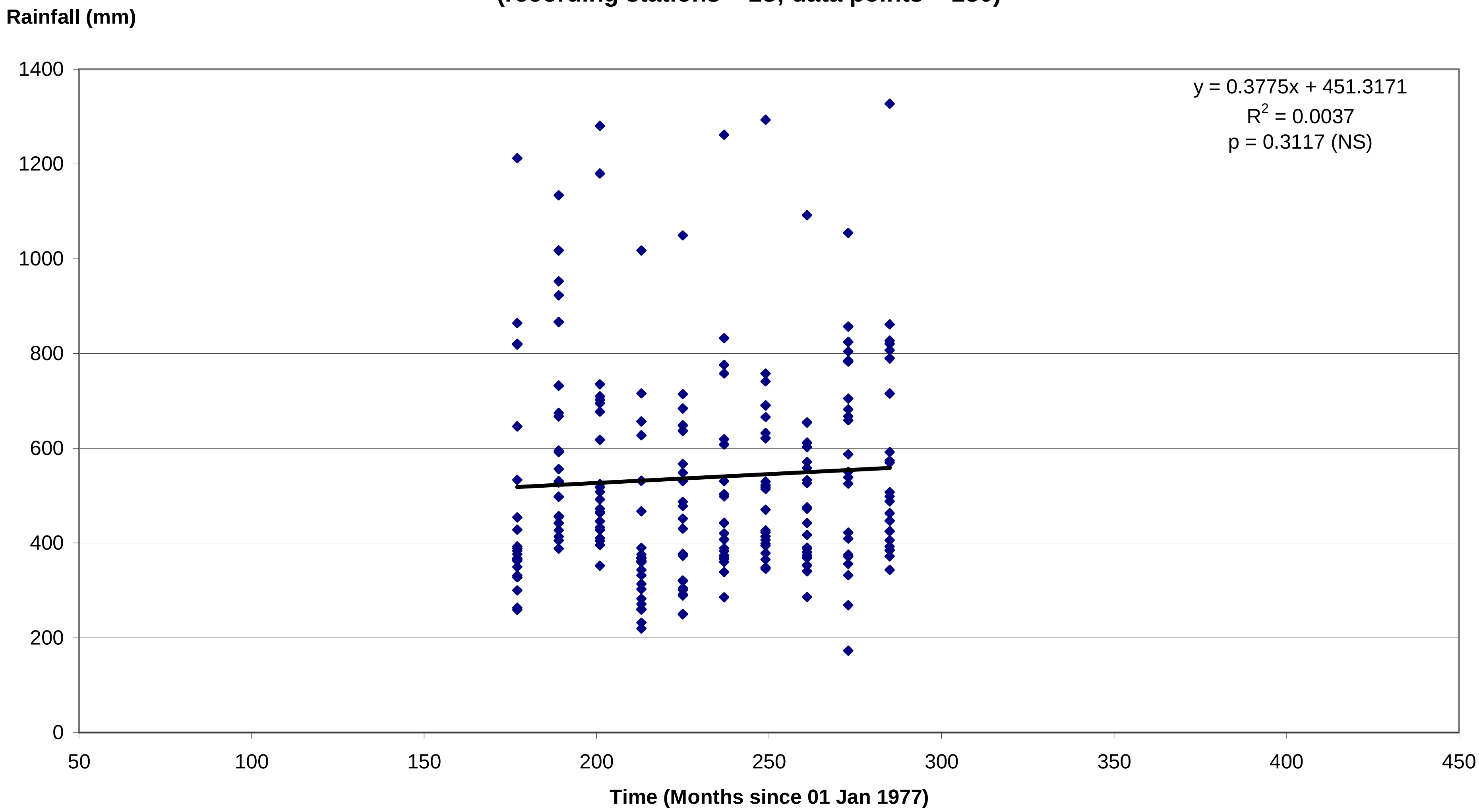
Appendix 38. 1981-2000 '12 months prior to September' Rainfalls and Regression of Rainfalls (recording stations = 21; data points = 420)



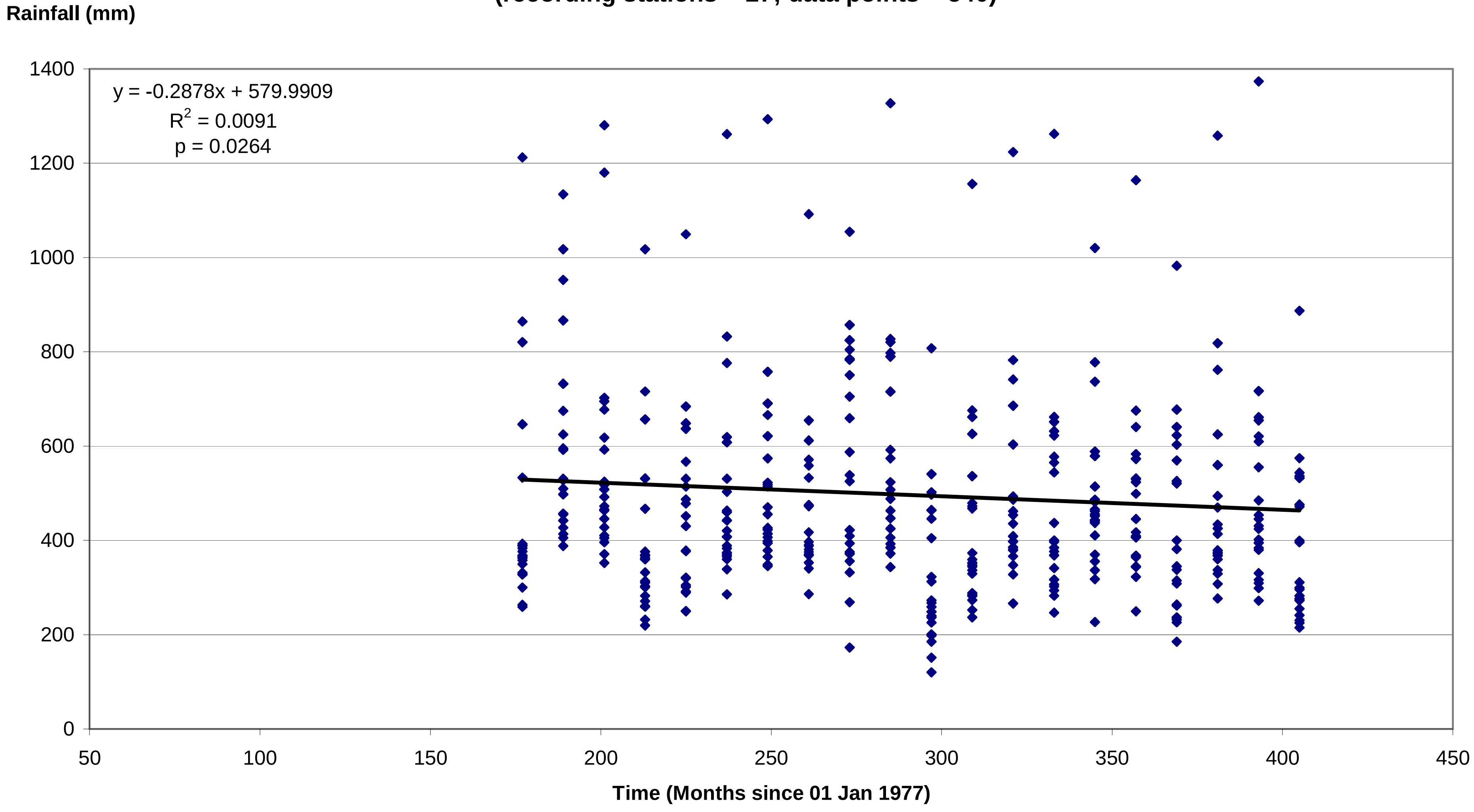
Appendix 39. 1981-2010 '12 months prior to September' Rainfalls and Regression of Rainfalls (recording stations = 21; data points = 630)



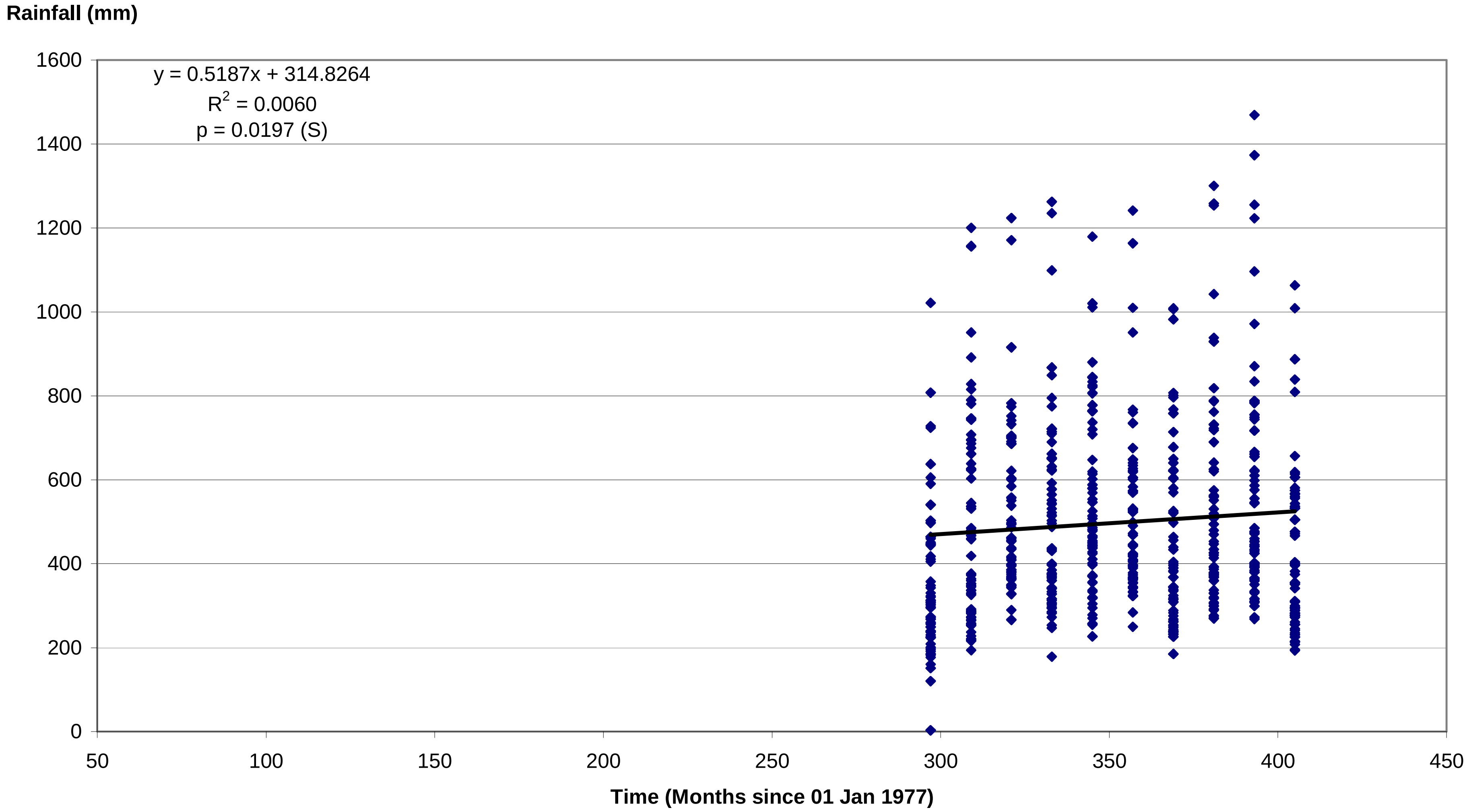
Appendix 40. 1991-2000 '12 months prior to September' Rainfalls and Regression of Rainfalls (recording stations = 28; data points = 280)

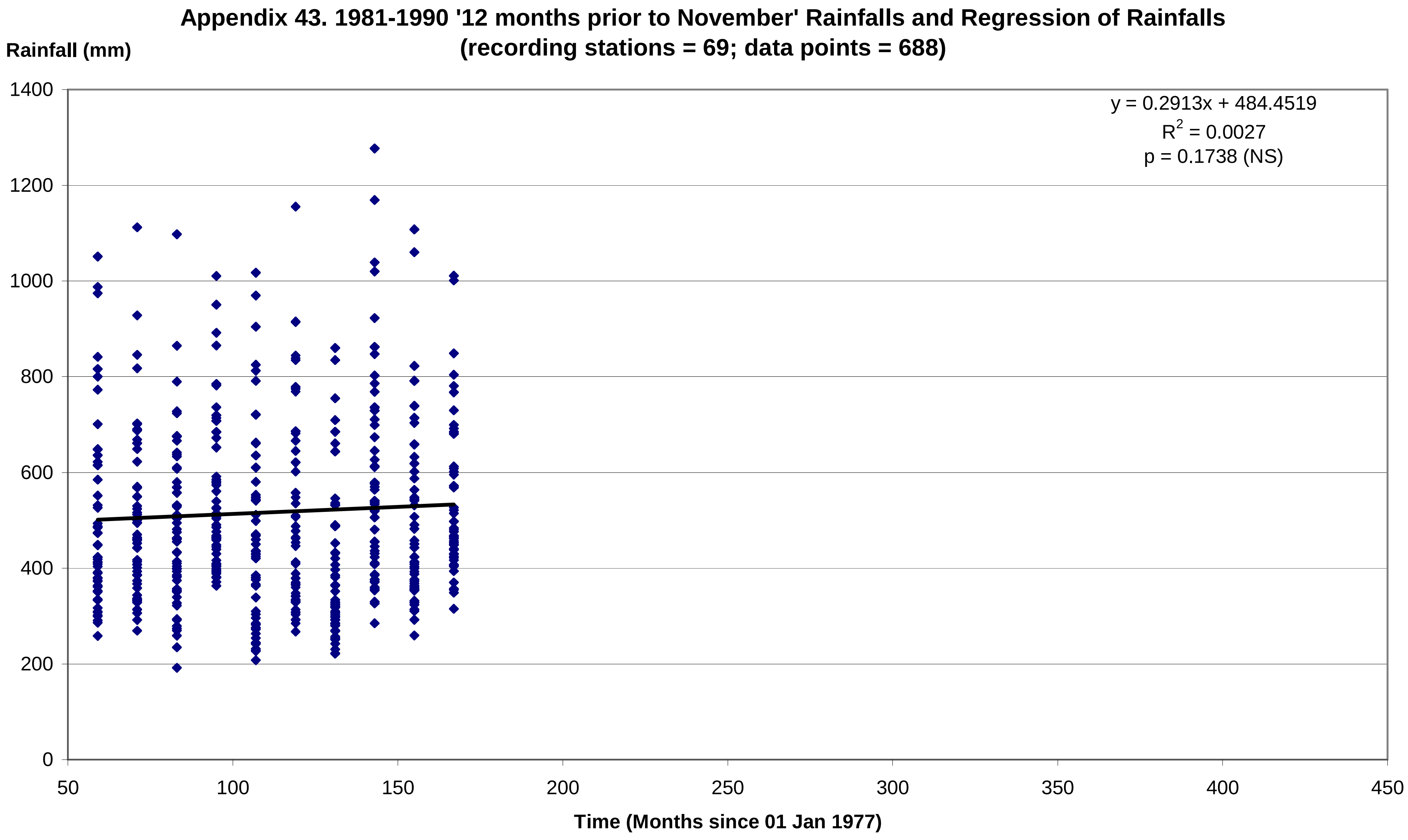


Appendix 41. 1991-2010 '12 months prior to September' Rainfalls and Regression of Rainfalls (recording stations = 27; data points = 540)



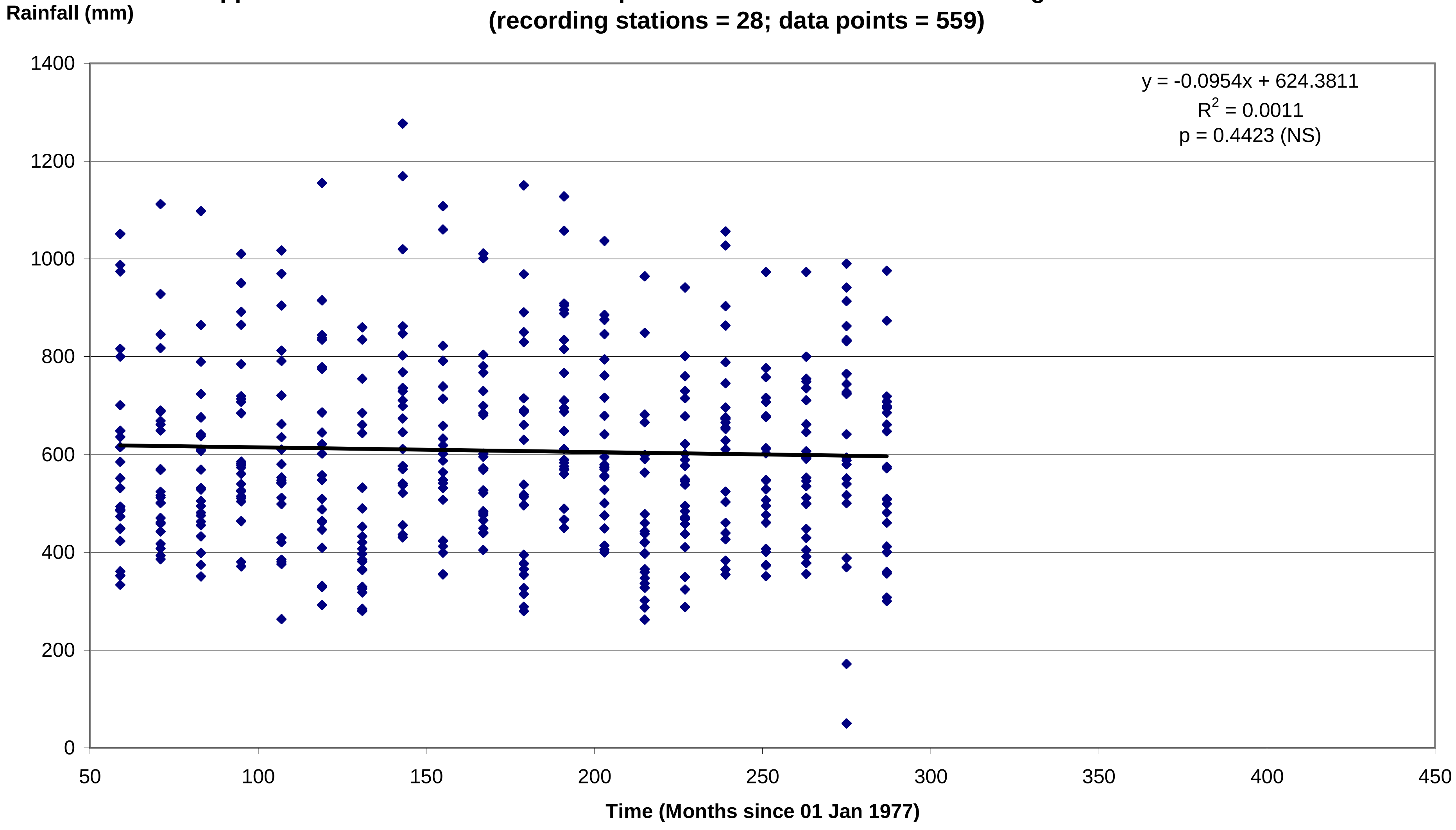
Appendix 42. 2001-2010 '12 months prior to September' Rainfalls and Regression of Rainfalls (recording stations =90; data points = 900)



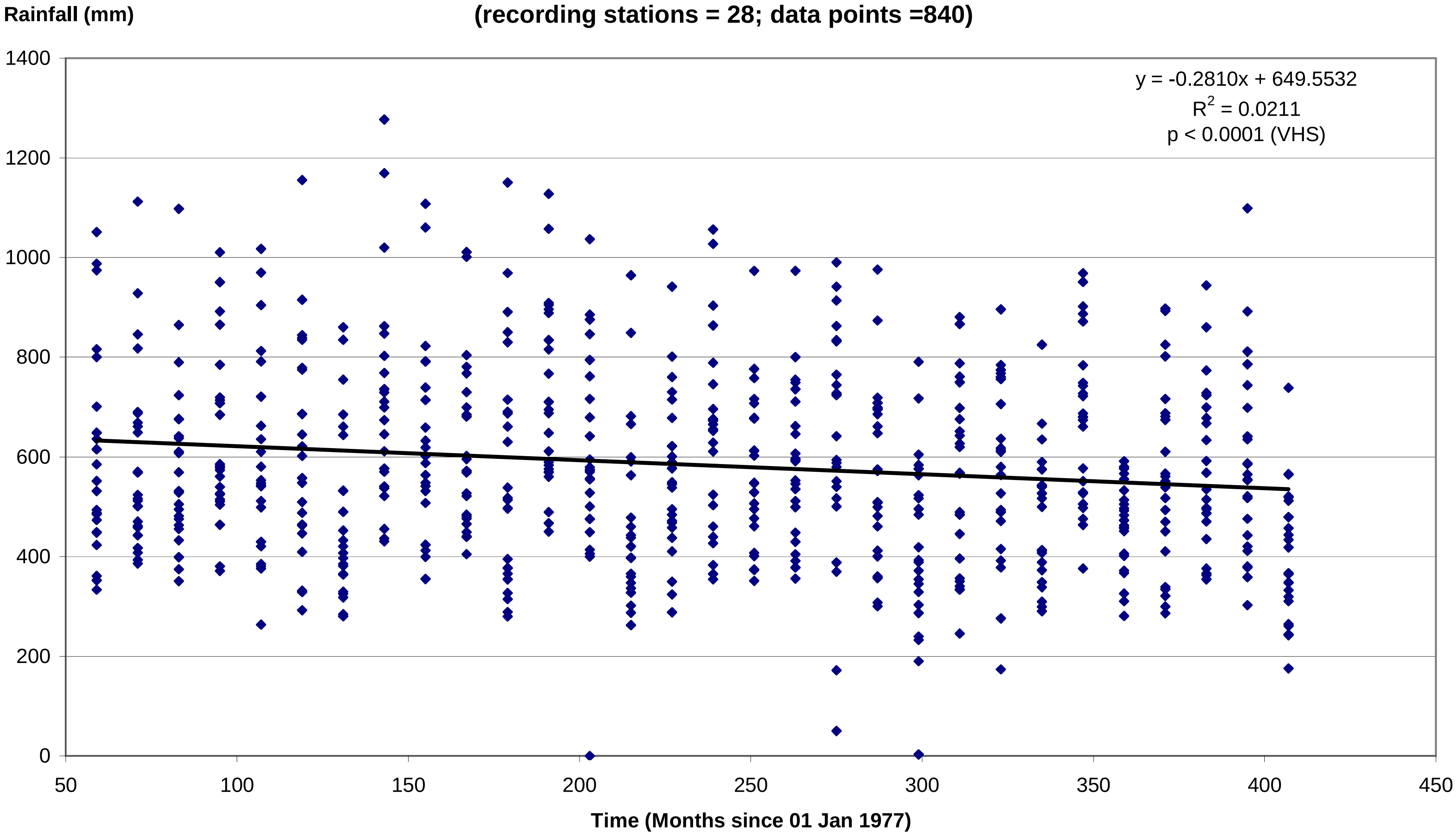


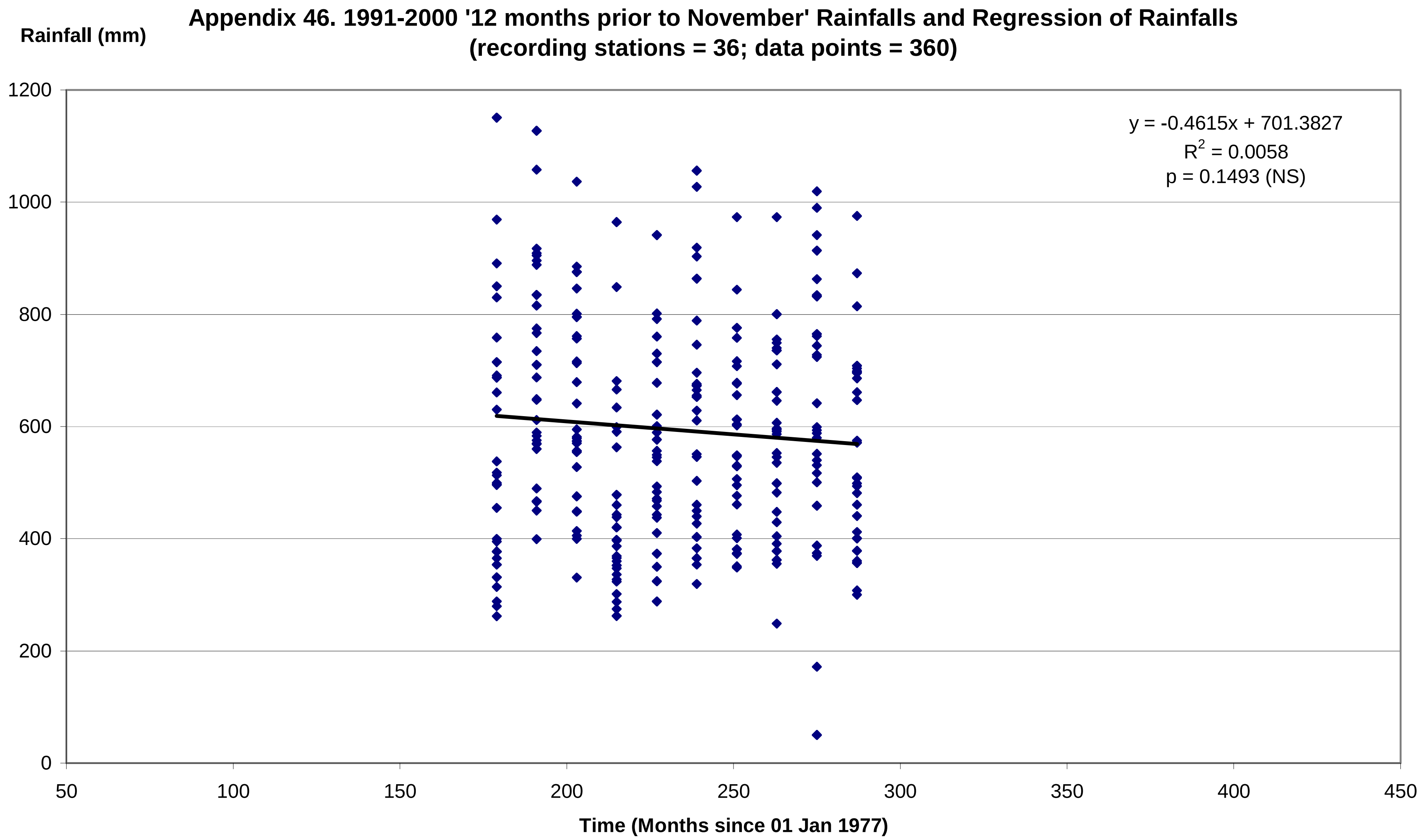
Appendix 43. 1981-1990 '12 months prior to November' Rainfalls and Regression of Rainfalls
(recording stations = 69; data points = 688)
Rainfall (mm)
1400
1200
1000
800
600
400
200
0
y = 0.2913x + 484.4519
R^2 = 0.0027
p = 0.1738 (NS)
50
100
150
200
250
300
350
400
450
Time (Months since 01 Jan 1977)

Appendix 44. 1981-2000 '12 months prior to November' Rainfalls and Regression of Rainfalls (recording stations = 28; data points = 559)



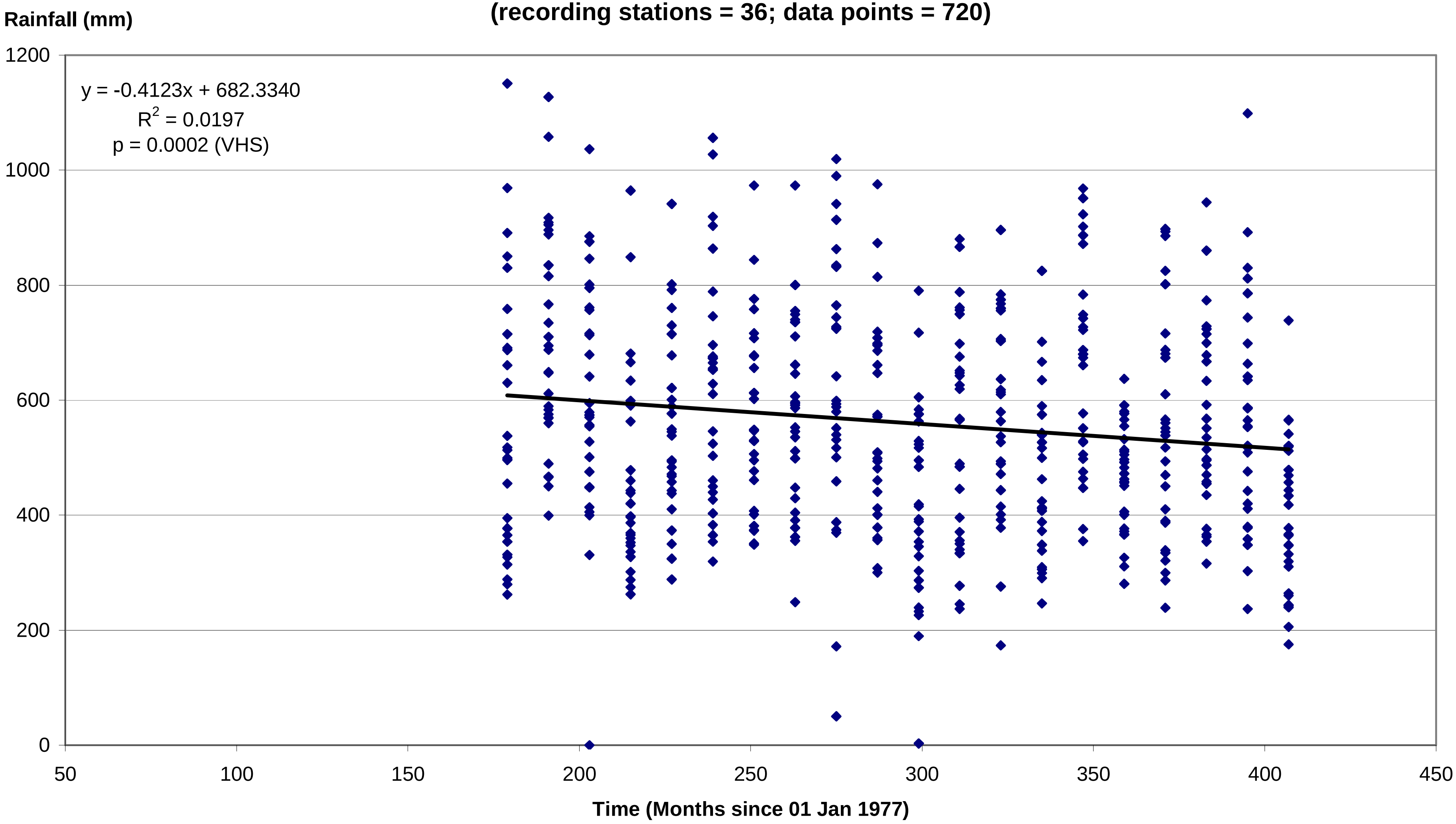
Appendix 45. 1981-2010 '12 months prior to November' Rainfalls and Regression of Rainfalls (recording stations = 28; data points =840)



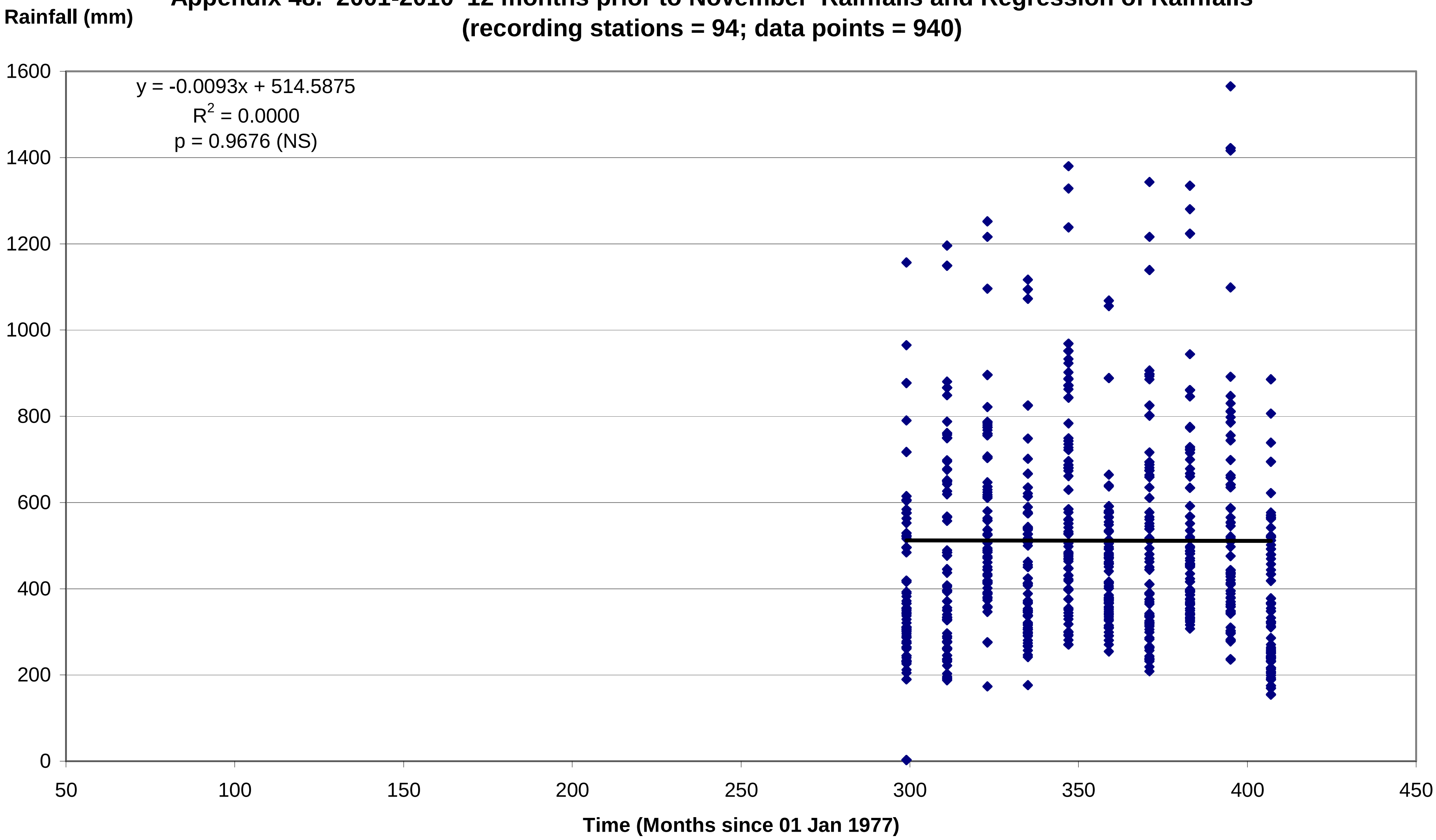


Appendix 46. 1991-2000 '12 months prior to November' Rainfalls and Regression of Rainfalls
(recording stations = 36; data points = 360)
Rainfall (mm)
y = -0.4615x + 701.3827
R^2 = 0.0058
p = 0.1493 (NS)
0
200
400
600
800
1000
1200
50
100
150
200
250
300
350
400
450
Time (Months since 01 Jan 1977)

Appendix 47. 1991-2010 '12 months prior to November' Rainfalls and Regressions of Rainfalls (recording stations = 36; data points = 720)



Appendix 48. 2001-2010 '12 months prior to November' Rainfalls and Regression of Rainfalls (recording stations = 94; data points = 940)



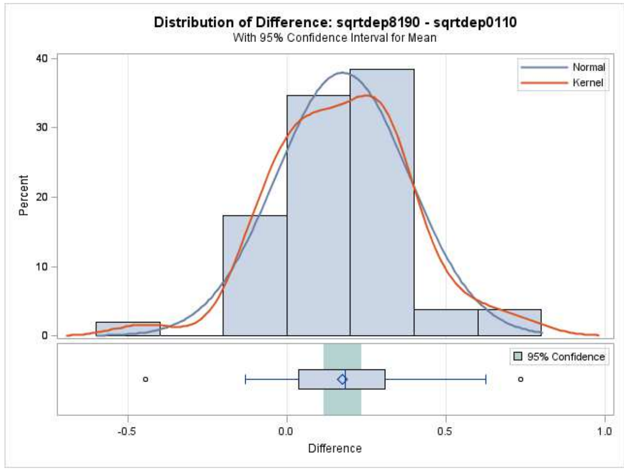
Appendix 49. Comparison between Sept 1981-1990 and Sept 2001-2010 Square Roots of Depths.

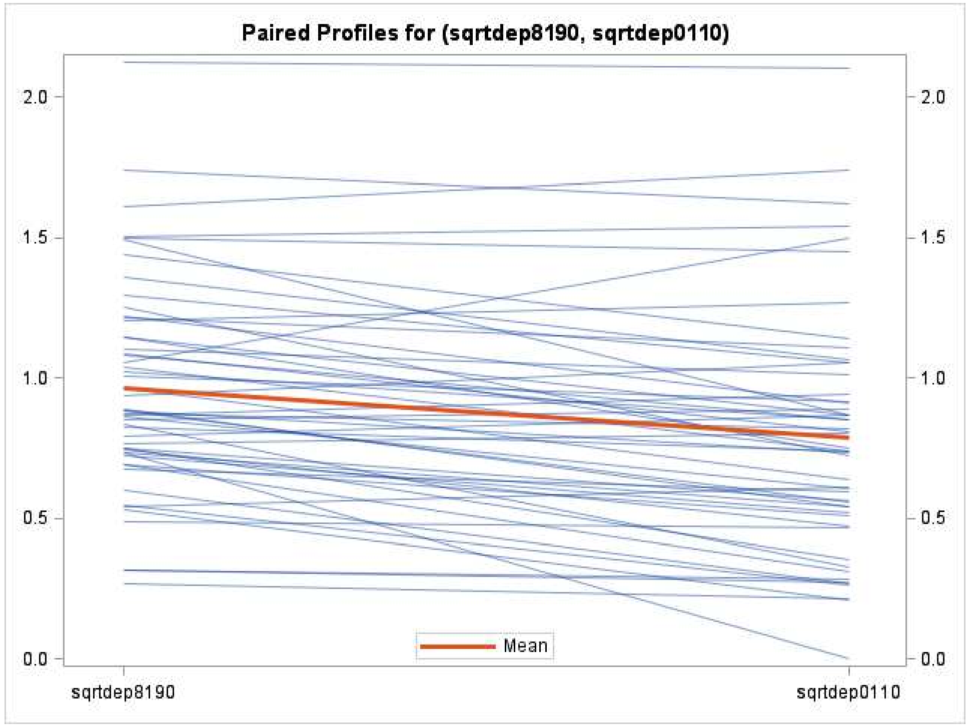
The wetlands (52) whose depths were recorded in every September of 1981-90 and 2001-10 were selected.
Square root of depth was then calculated for each of these wetlands in each year.
1981-90 and 2001-10 averages (means) of these square roots then calculated for each wetland.
Paired t-Test was then used to test for significant difference between 1981-90 and 2001-10 means.

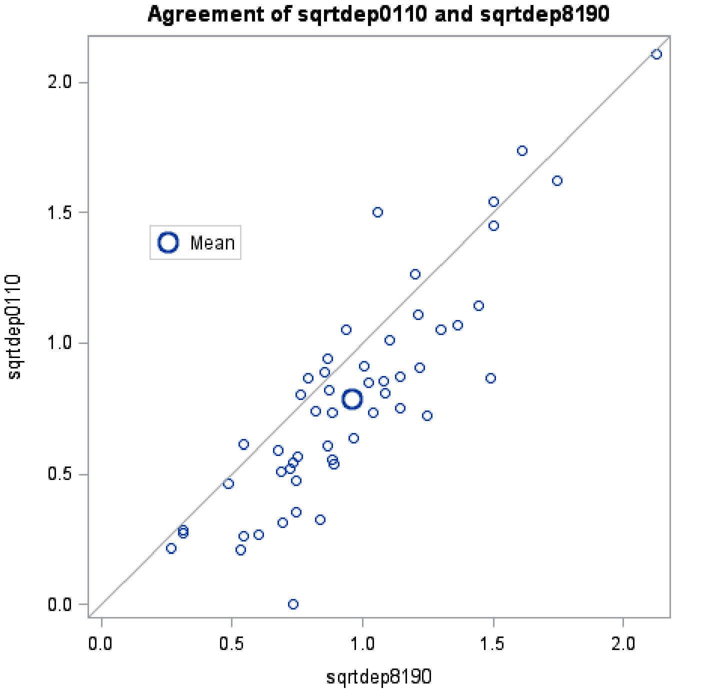
N	Mean	Std Dev	Std Err	Minimum	Maximum
52	0.1754	0.2101	0.0291	-0.4456	0.7343

Mean	95% CL Mean		Std Dev	95% CL Std Dev	
0.1754	0.1170	0.2339	0.2101	0.1761	0.2605

DF	t Value	Pr > |t|
51	6.02	<.0001







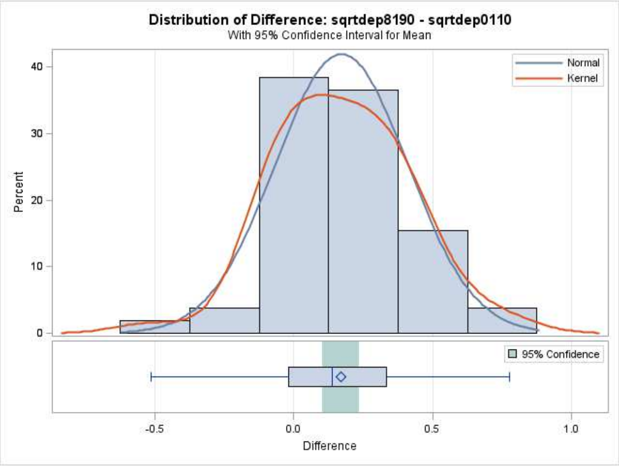
Appendix 50. Comparison between Nov 1981-1990 and Nov 2001-2010 Square Root of Depths.

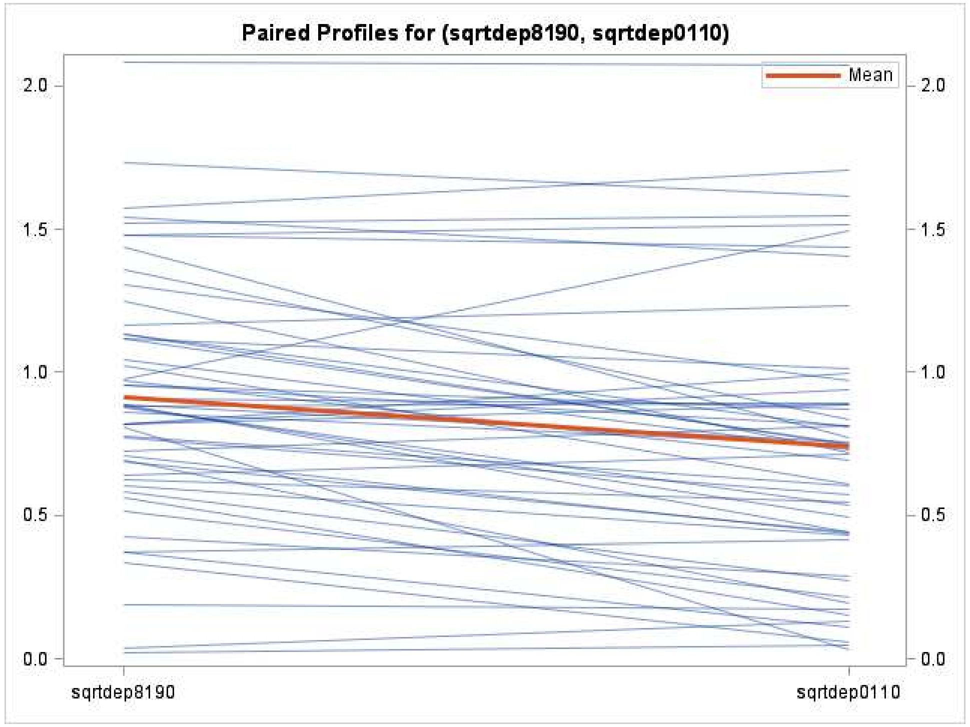
The wetlands (52) whose depths were recorded in every November of 1981-90 and 2001-10 were selected.
Square root of depth was then calculated for each of these wetlands in each year.
1981-90 and 2001-10 averages (means) of these square roots then calculated for each wetland.
Paired t -Test was then used to test for significant difference between 1981-90 and 2001-10 means.

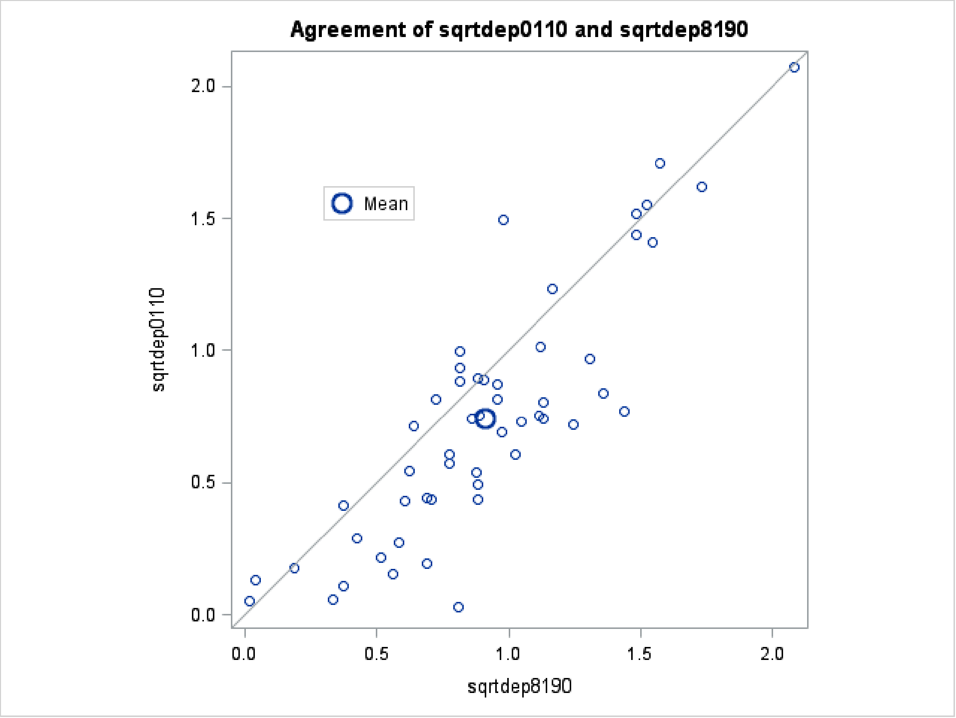
N	Mean	Std Dev	Std Err	Minimum	Maximum
52	0.1711	0.2381	0.0330	-0.5155	0.7776

Mean	95% CL Mean		Std Dev	95% CL Std Dev	
0.1711	0.1048	0.2374	0.2381	0.1995	0.2953

DF	t Value	Pr > |t|
51	5.18	<.0001







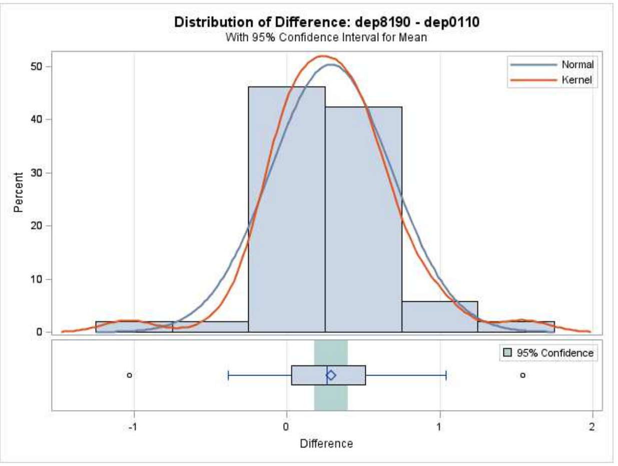
Appendix 51. Comparison between Sept 1981-1990 and Sept 2001-2010 Depths.

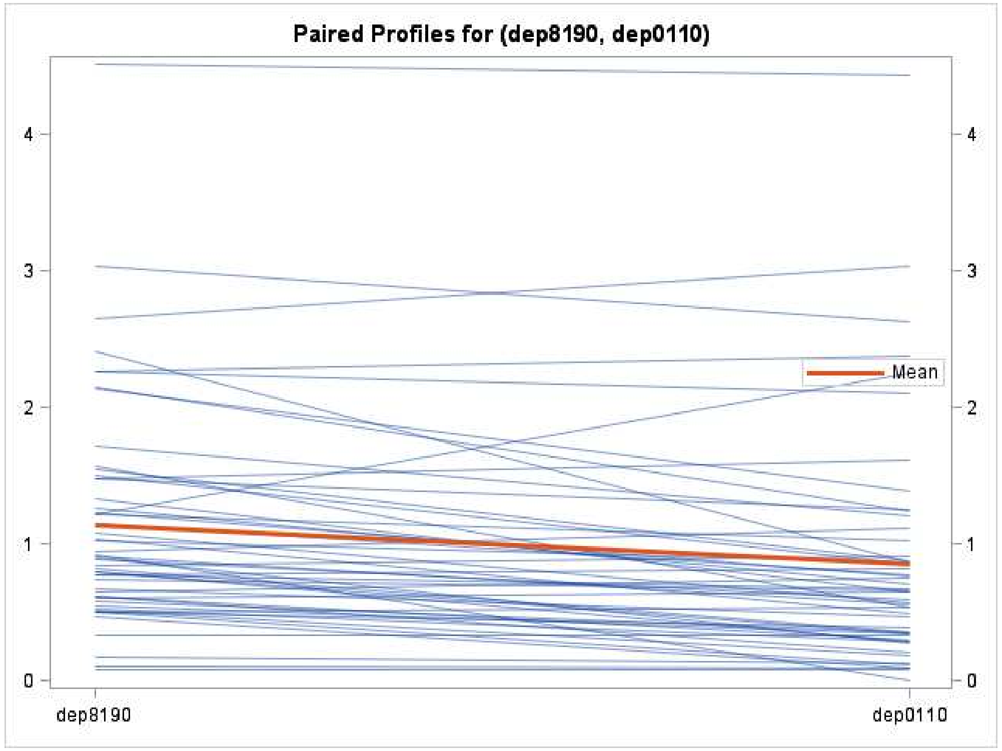
The wetlands (52) whose depths were recorded in every September of 1981-90 and 2001-10 were selected.
The 1981-90 and 2001-10 average (mean) depths of each of these wetlands were then calculated.
Paired t -Test was then used to test for significant difference between 1981-90 and 2001-10 means.

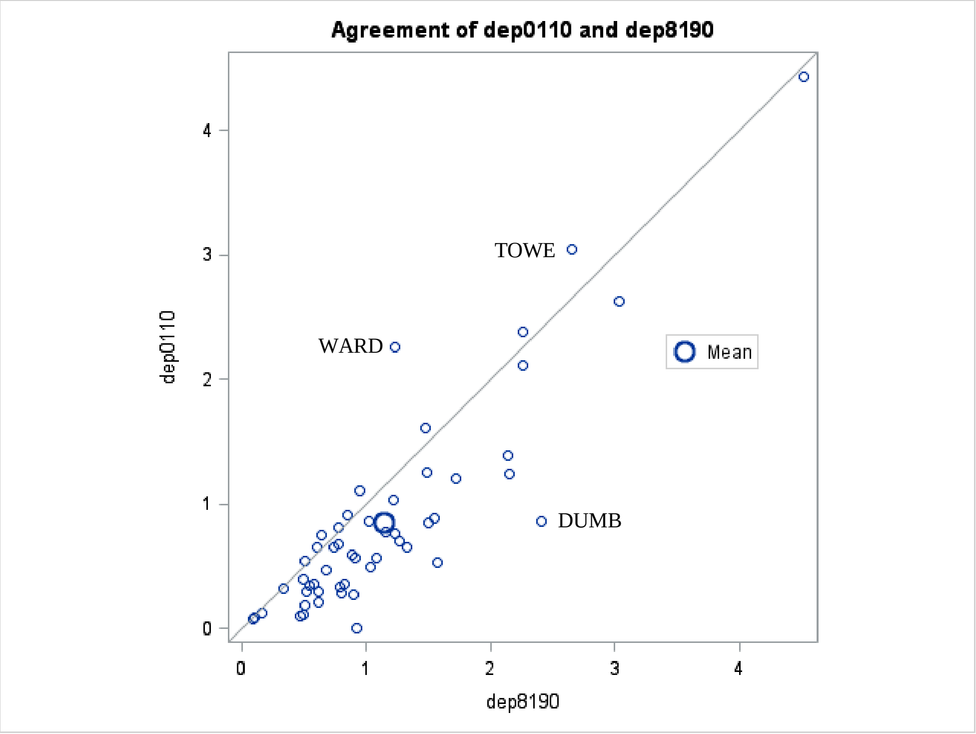
N	Mean	Std Dev	Std Err	Minimum	Maximum
52	0.2878	0.3962	0.0549	-1.0330	1.5450

Mean	95% CL Mean		Std Dev	95% CL Std Dev	
0.2878	0.1775	0.3981	0.3962	0.3320	0.4913

DF	t Value	Pr > |t|
51	5.24	<.0001







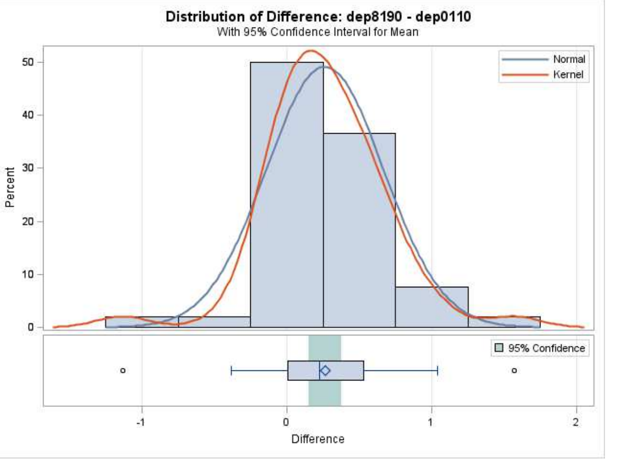
Appendix 52. Comparison between Nov 1981-1990 and Nov 2001-2010 Depths.

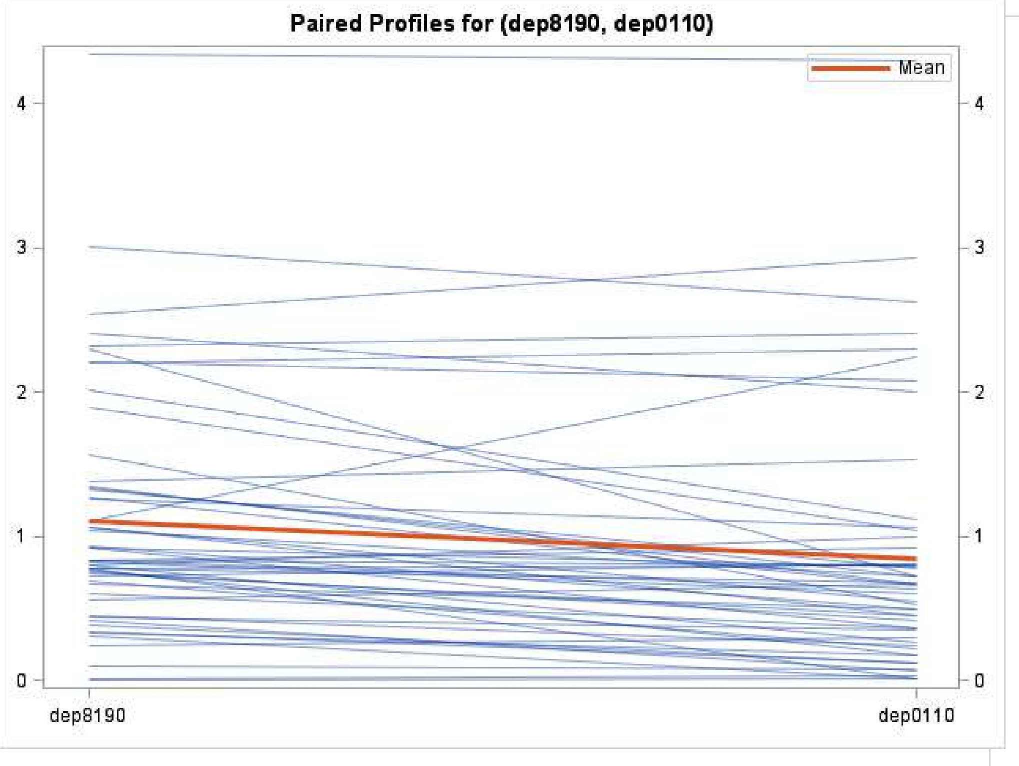
The wetlands (52) whose depths were recorded in every November of 1981-90 and 2001-10 were selected.
The 1981-90 and 2001-10 average (mean) depths of each of these wetlands were then calculated.
Paired t -Test was then used to test for significant difference between 1981-90 and 2001-10 means.

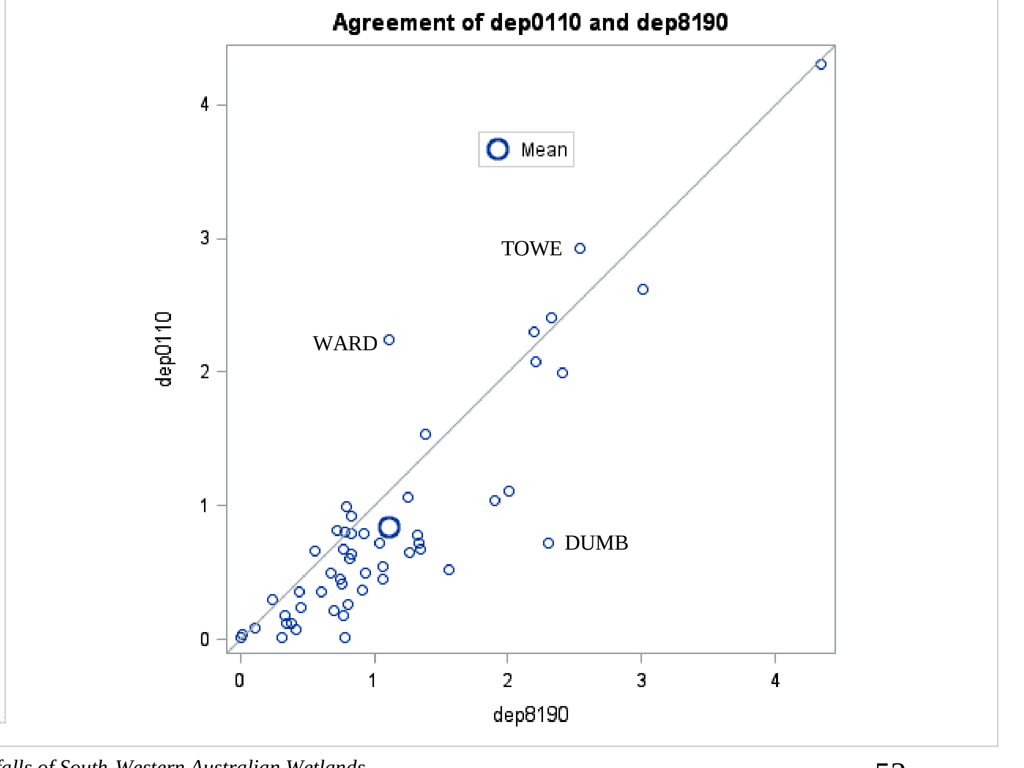
N	Mean	Std Dev	Std Err	Minimum	Maximum
52	0.2628	0.4059	0.0563	-1.1325	1.5690

Mean	95% CL Mean		Std Dev	95% CL Std Dev	
0.2628	0.1498	0.3758	0.4059	0.3402	0.5034

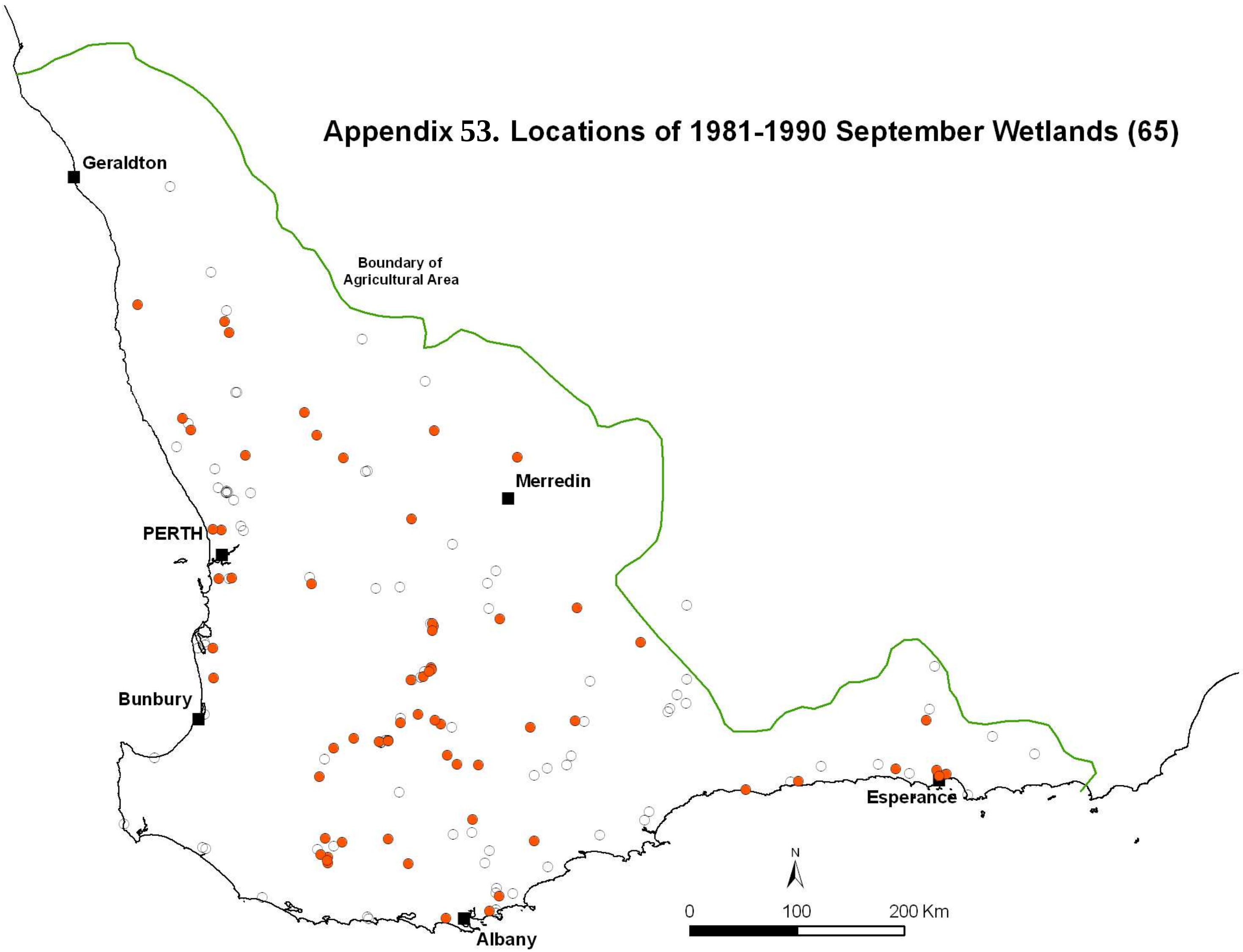
DF	t Value	Pr > |t|
51	4.67	<.0001



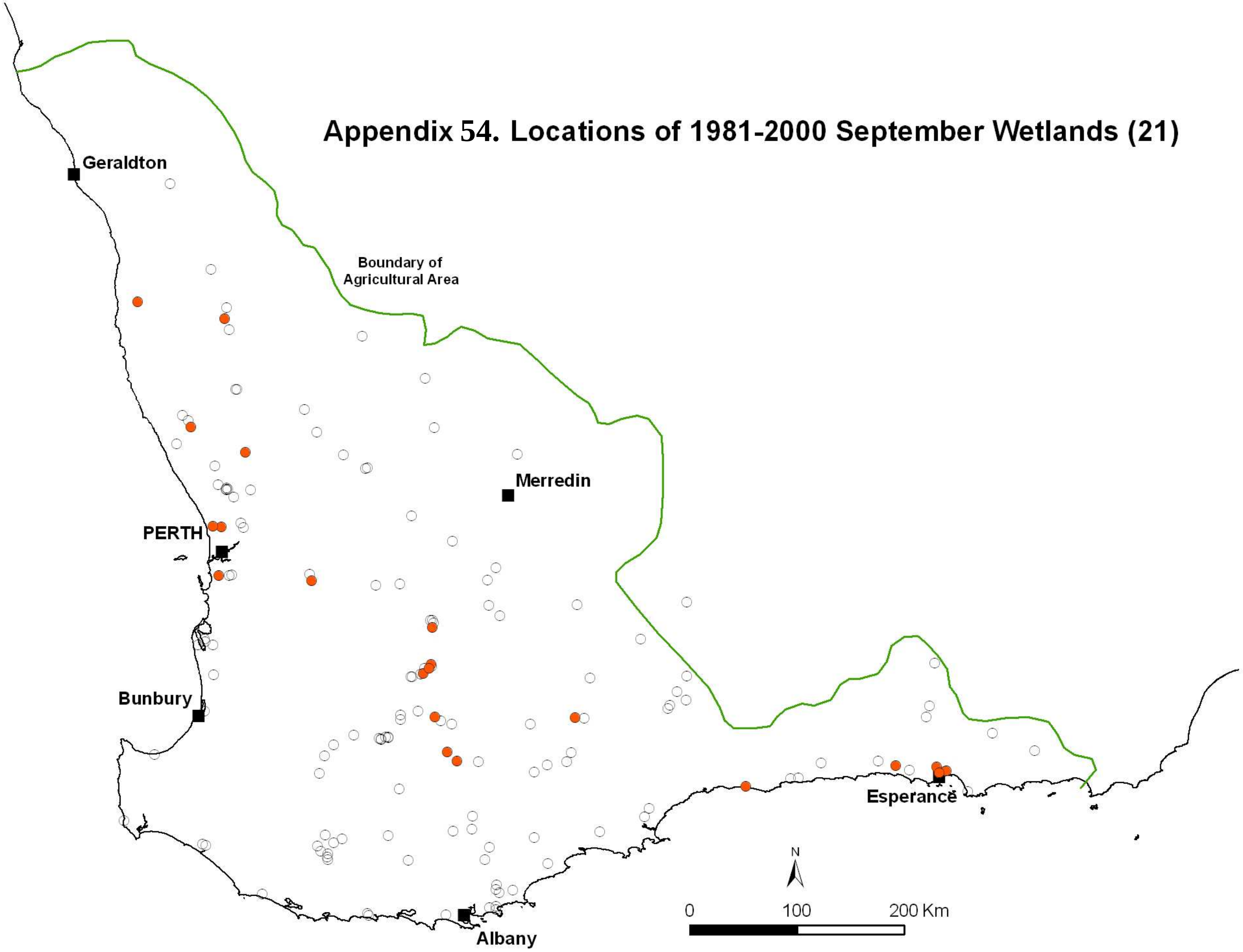


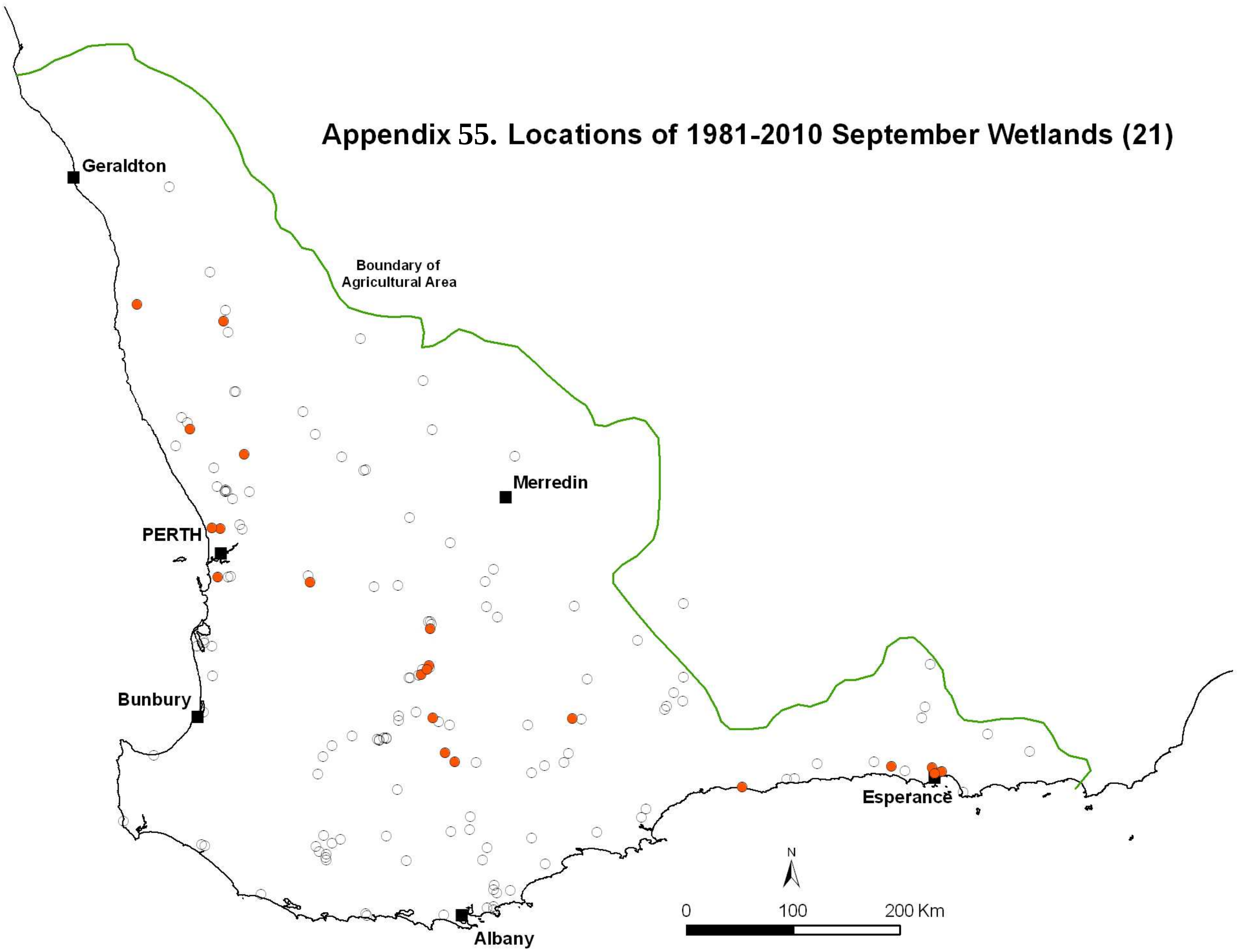


Appendix 53. Locations of 1981-1990 September Wetlands (65)

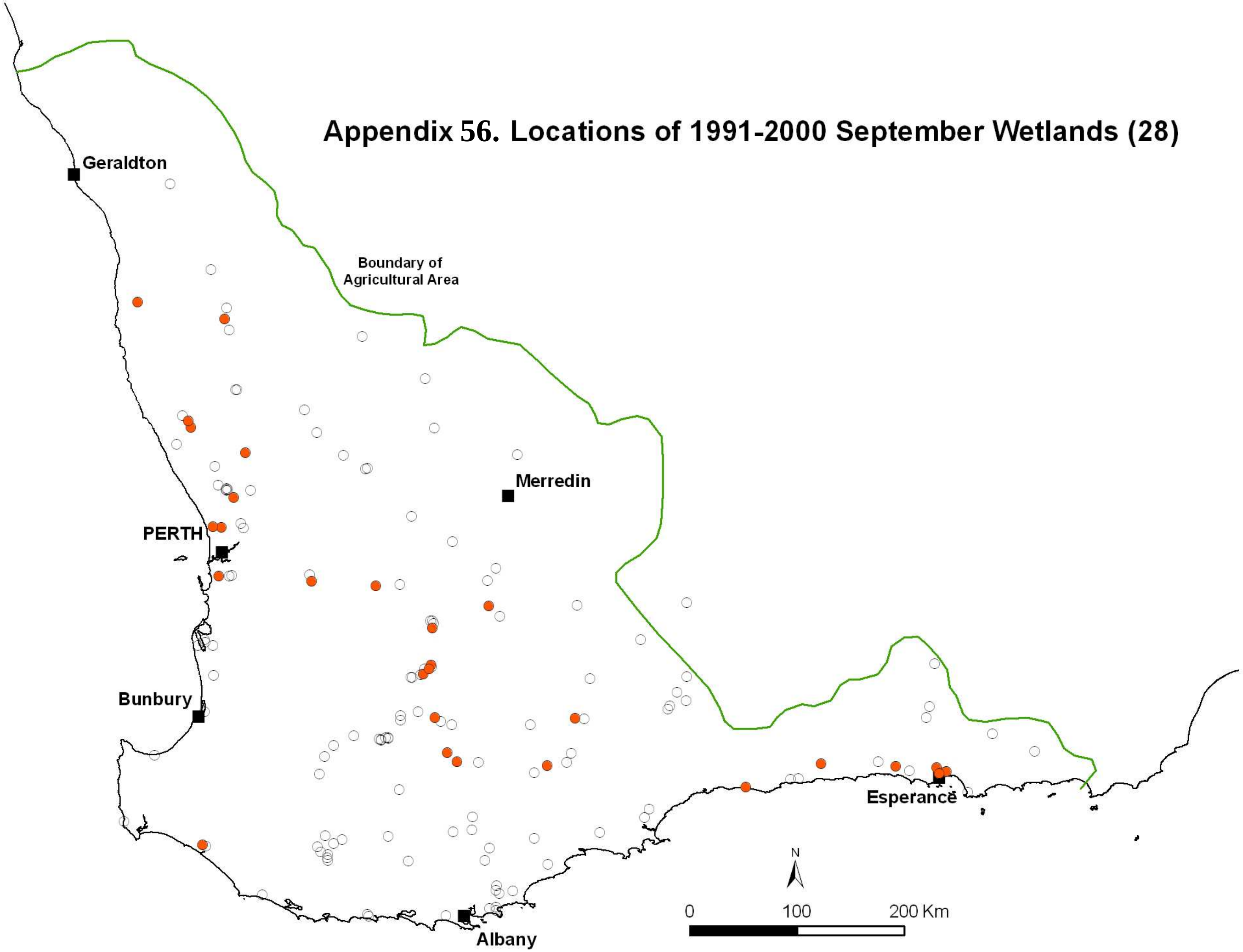


Appendix 54. Locations of 1981-2000 September Wetlands (21)

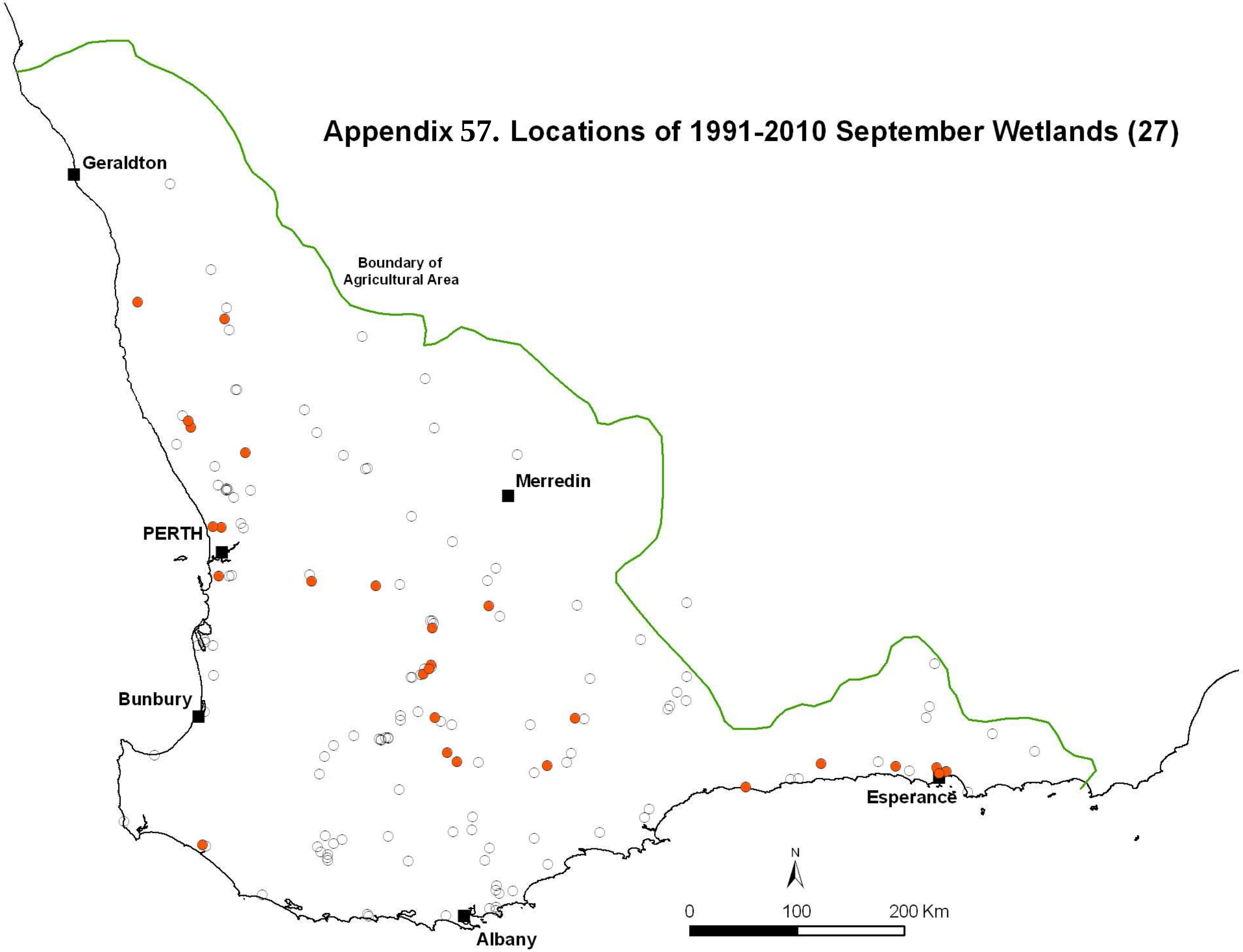



Appendix 55. Locations of 1981-2010 September Wetlands (21)
Geraldton
Boundary of
Agricultural Area
Merredin
PERTH
Bunbury
Esperance
Albany
N
0
100
200 Km

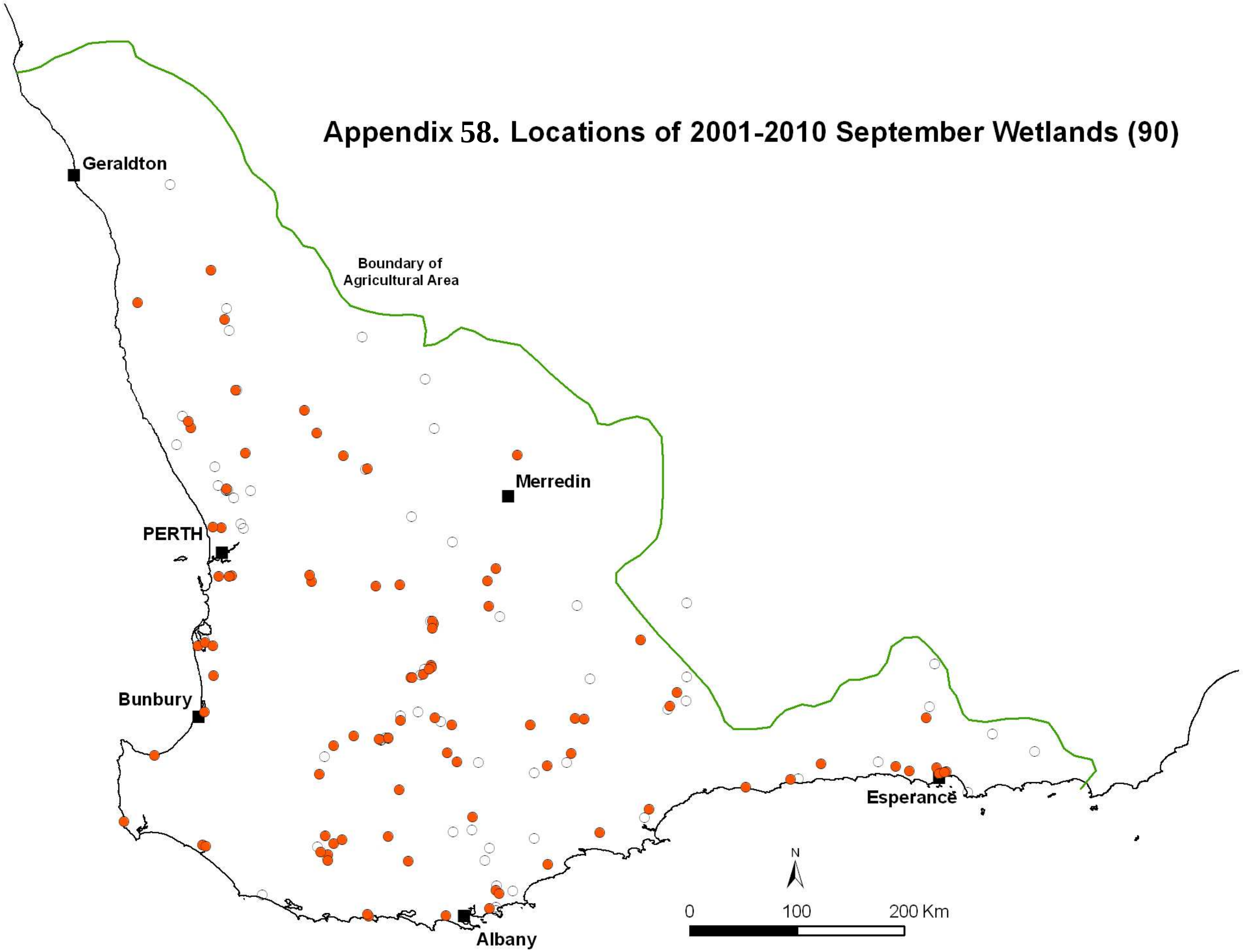
Appendix 56. Locations of 1991-2000 September Wetlands (28)



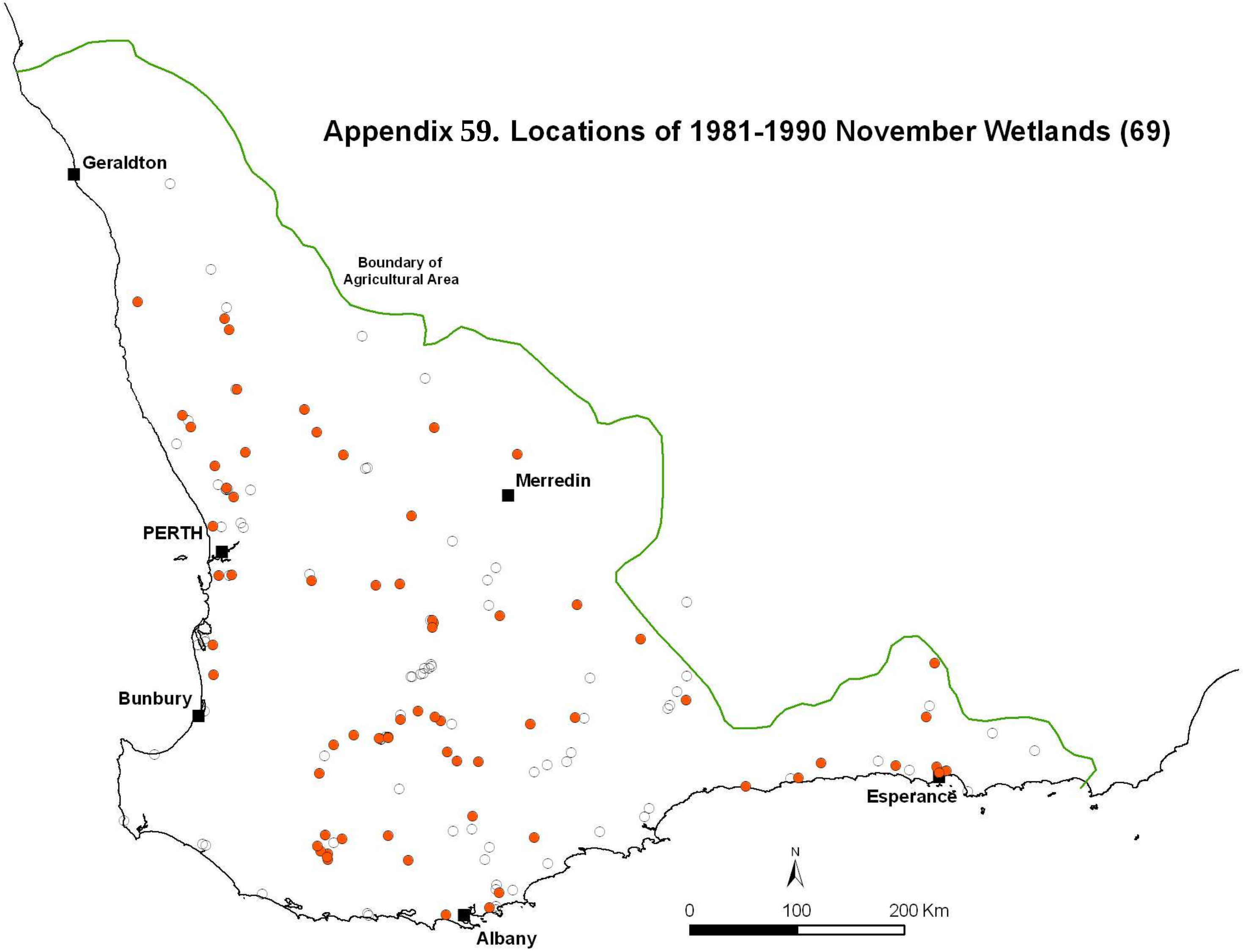
Appendix 57. Locations of 1991-2010 September Wetlands (27)

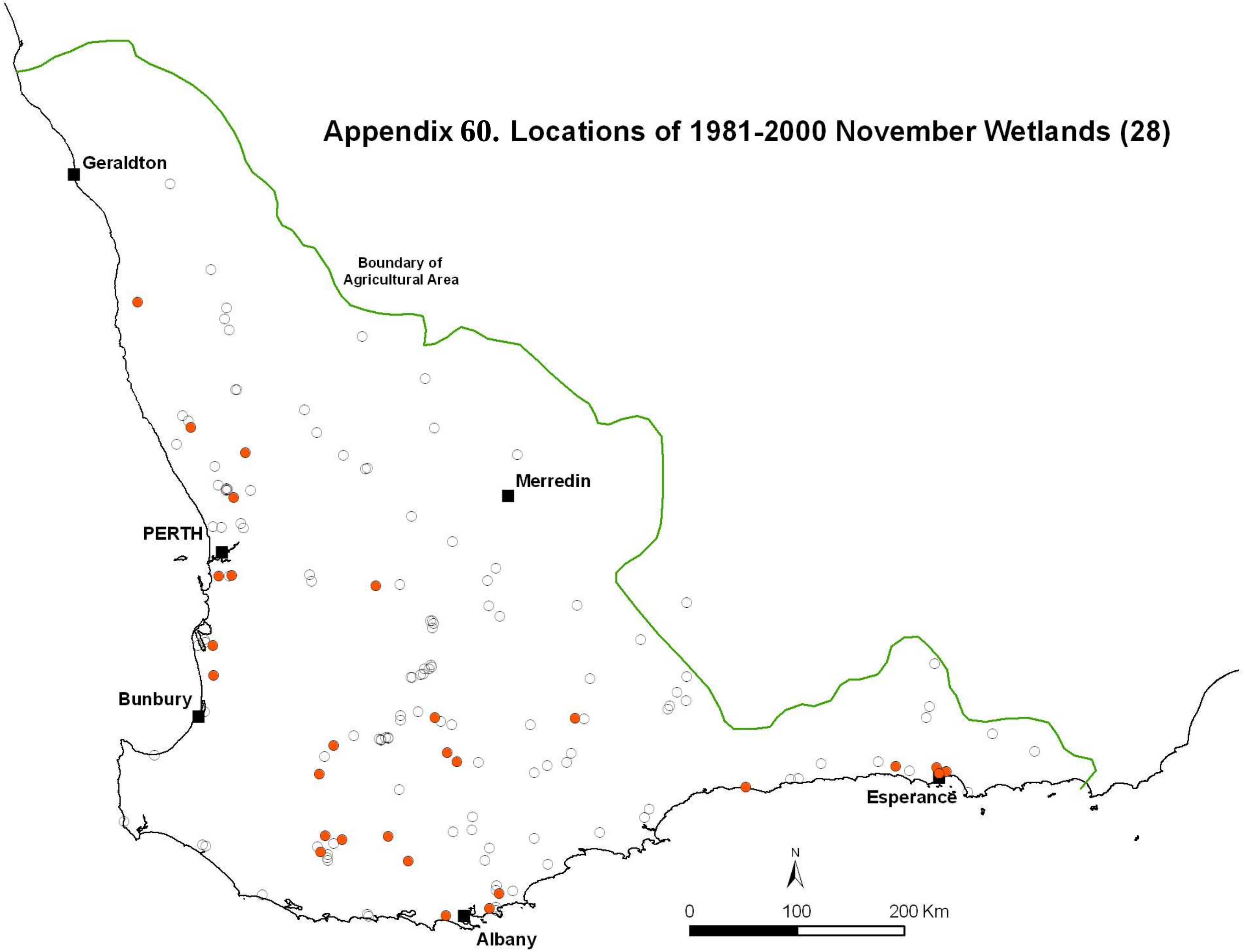


Appendix 58. Locations of 2001-2010 September Wetlands (90)

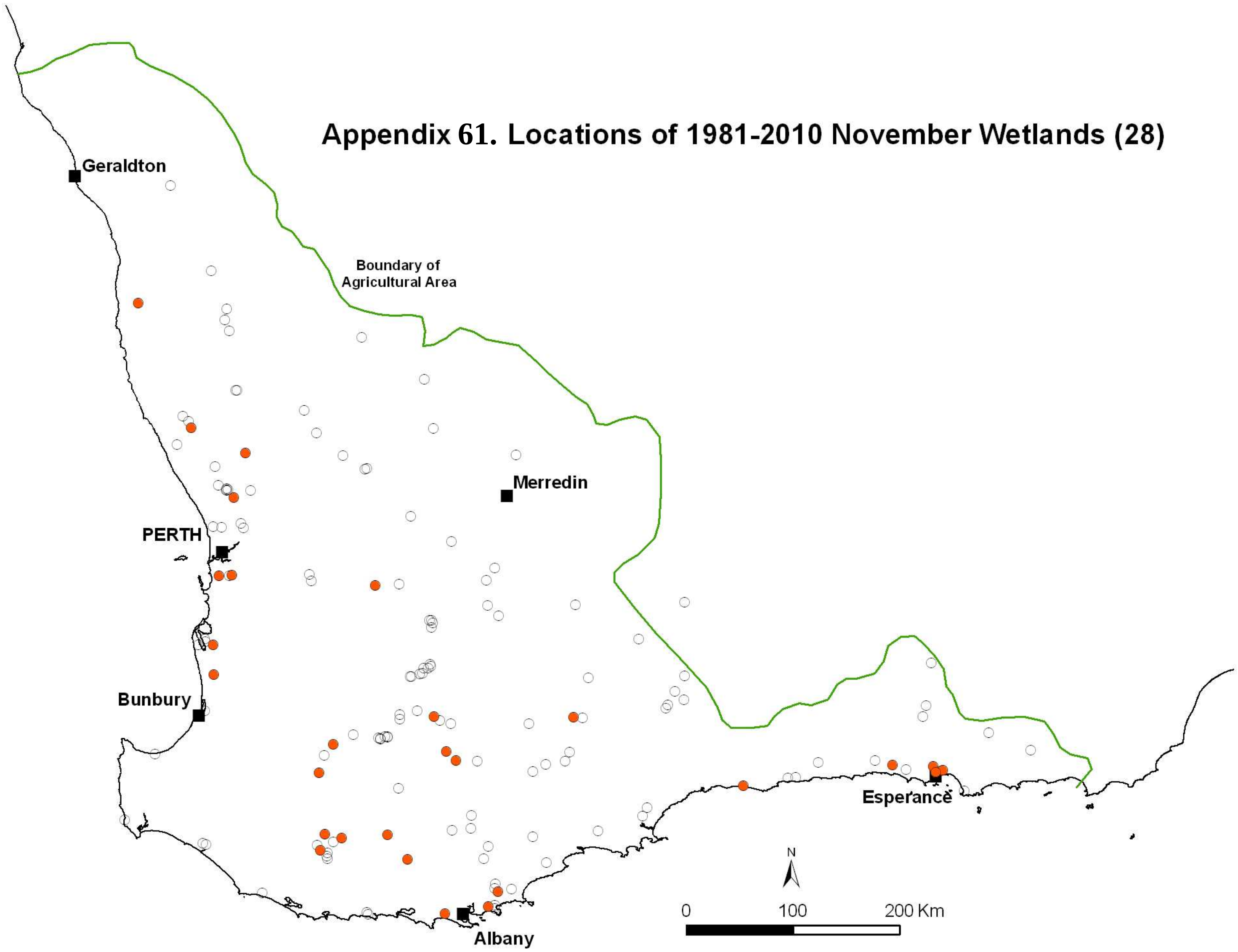


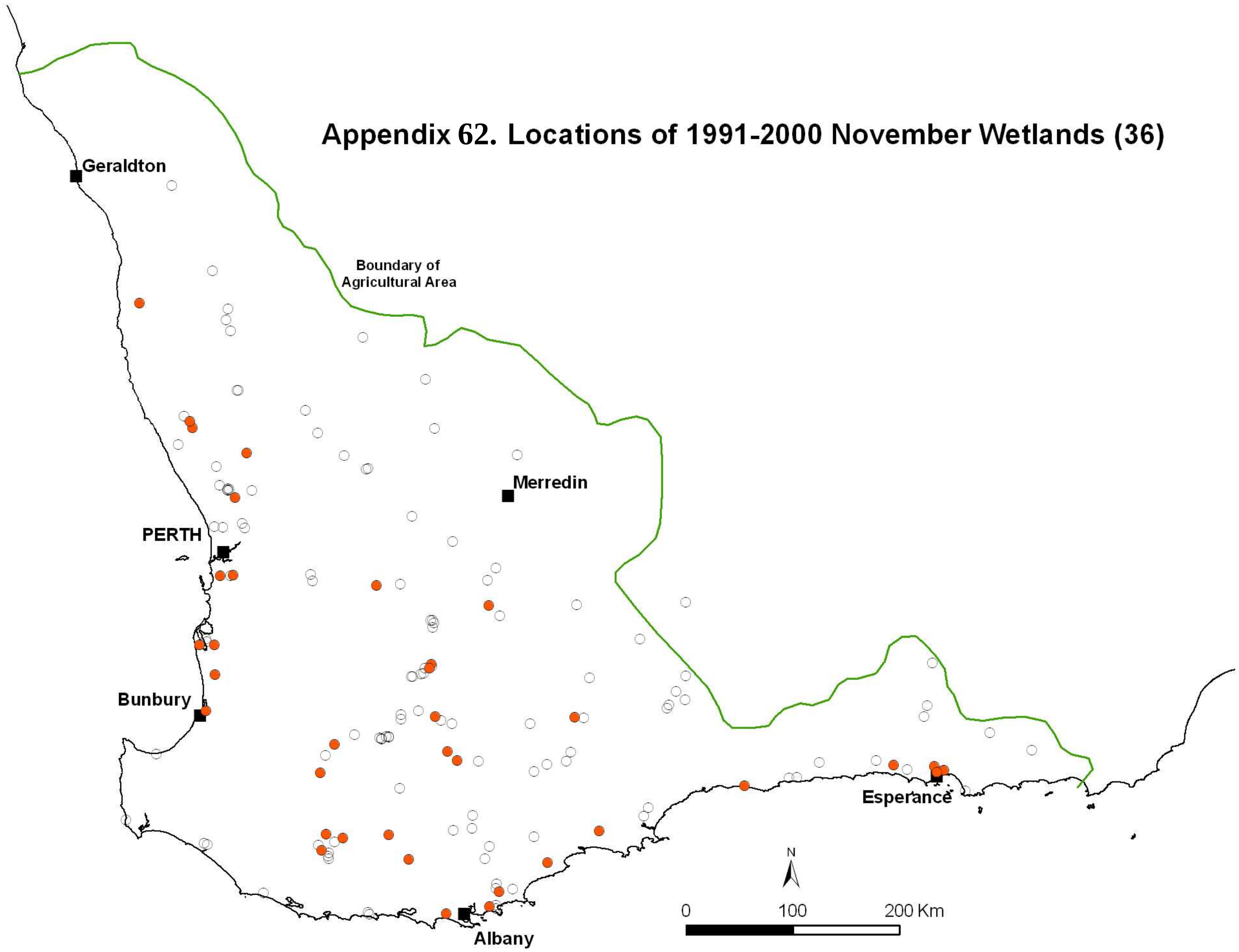
Appendix 59. Locations of 1981-1990 November Wetlands (69)

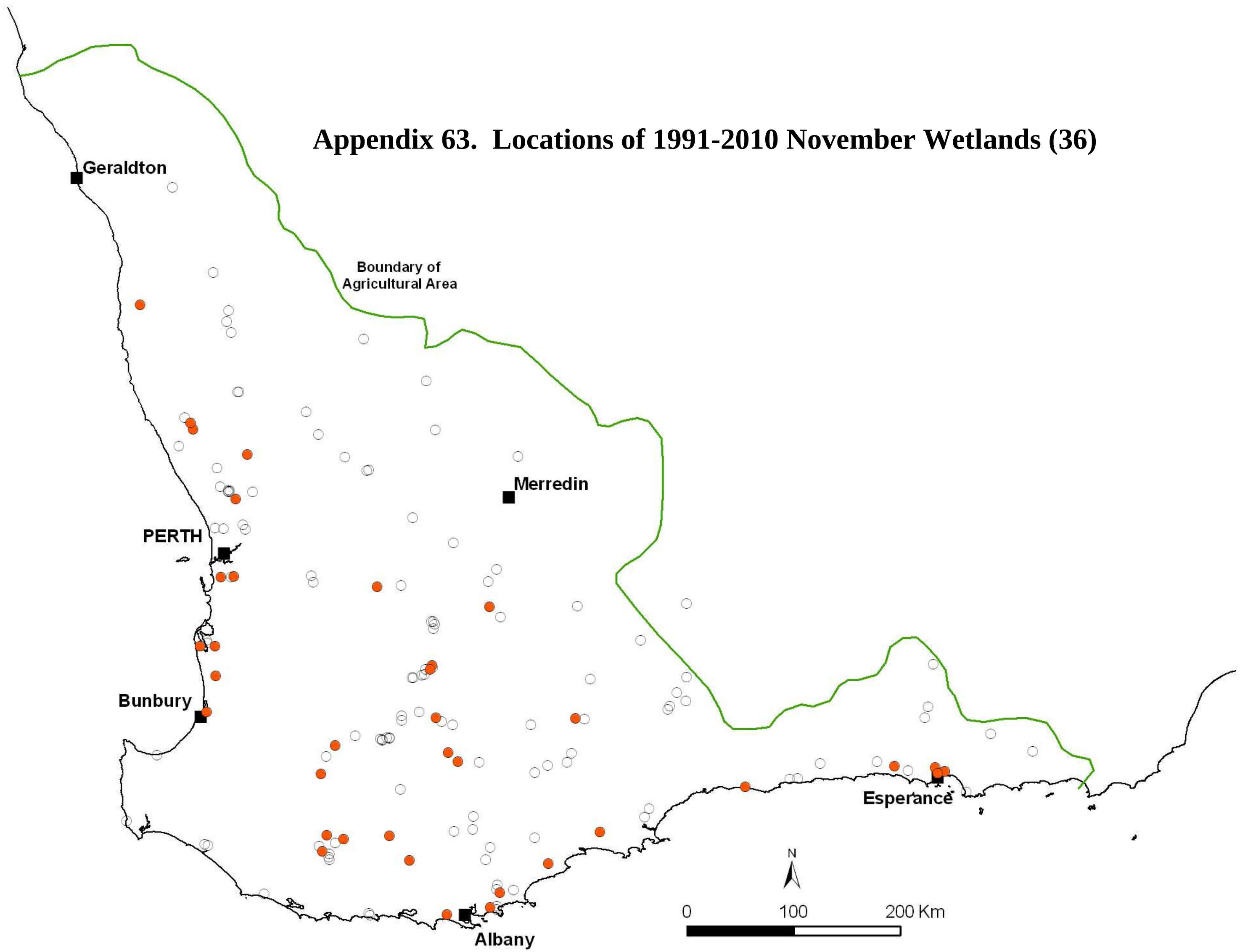



Appendix 60. Locations of 1981-2000 November Wetlands (28)
Geraldton
Boundary of
Agricultural Area
Merredin
PERTH
Bunbury
Esperance
Albany
N
0
100
200 Km

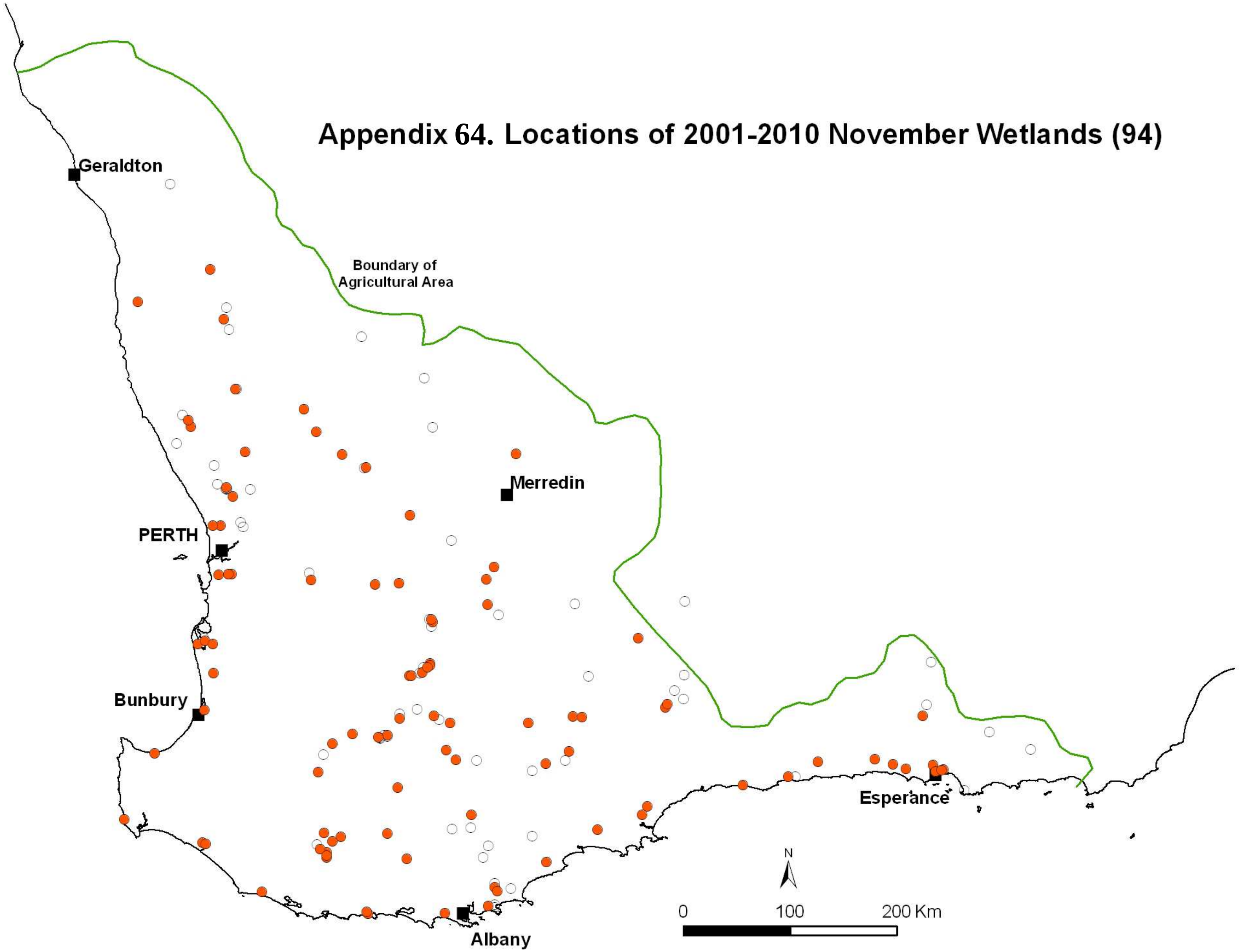
Appendix 61. Locations of 1981-2010 November Wetlands (28)

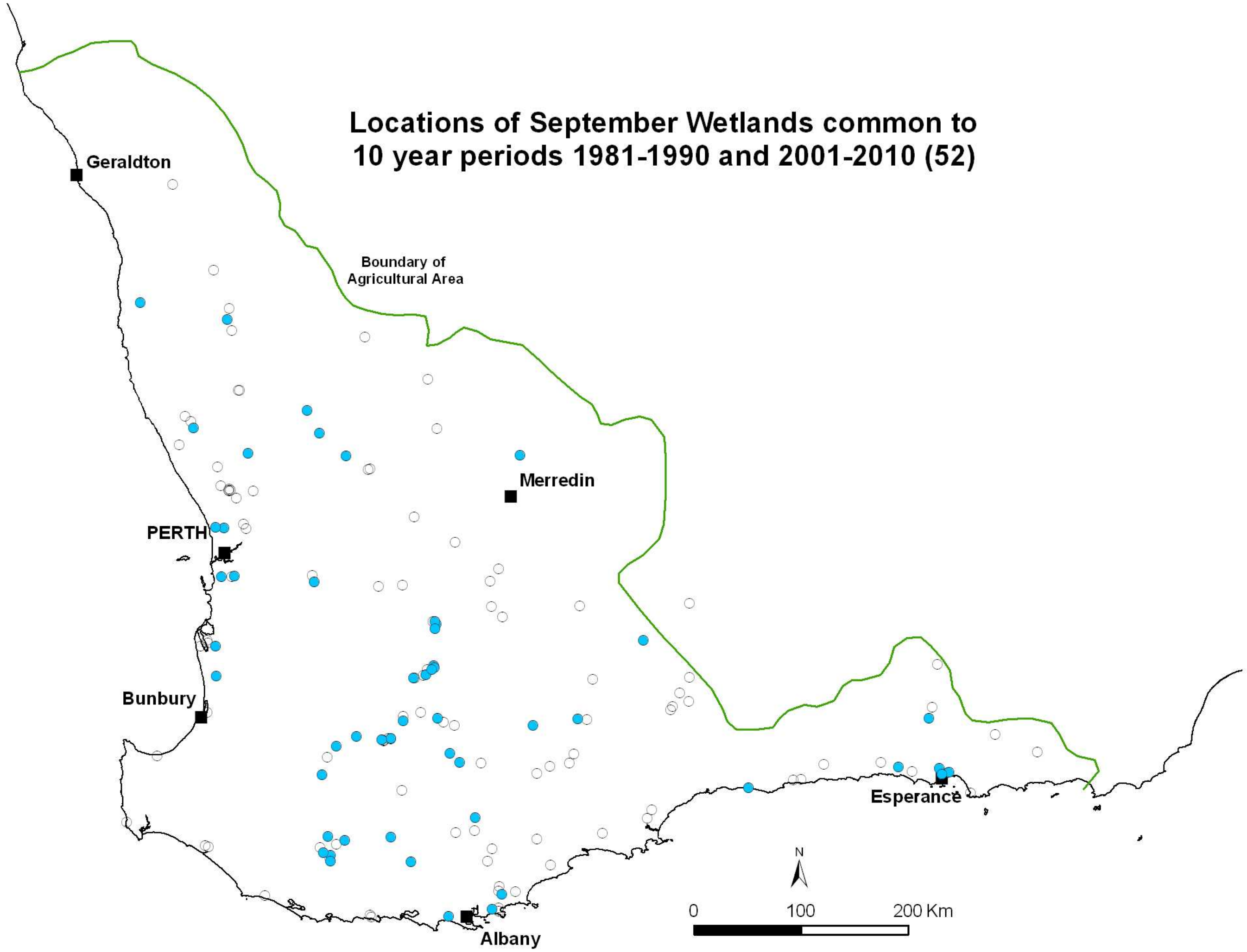



Appendix 62. Locations of 1991-2000 November Wetlands (36)
Geraldton
Boundary of
Agricultural Area
Merredin
PERTH
Bunbury
Esperance
Albany
N
0
100
200 Km

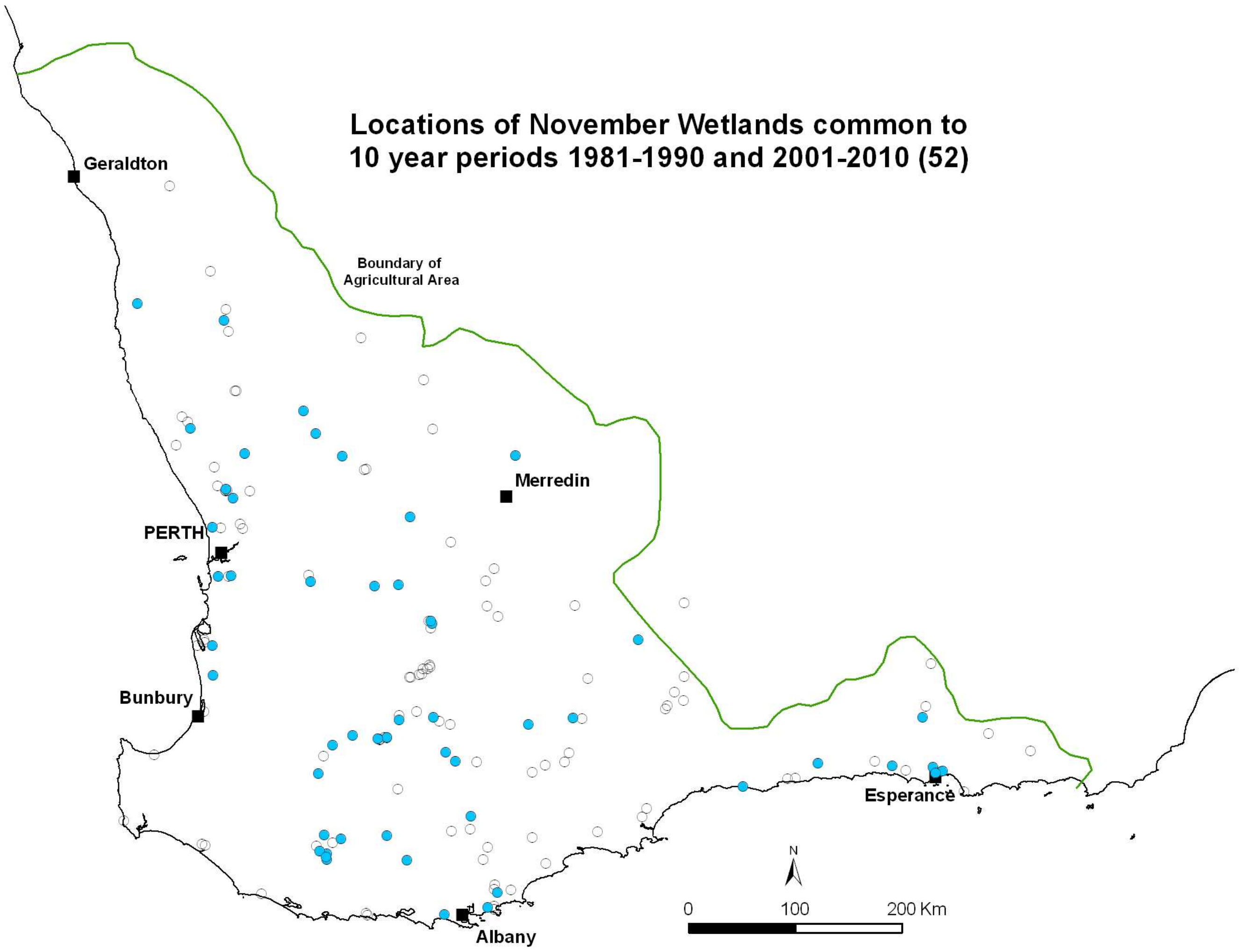

Appendix 63. Locations of 1991-2010 November Wetlands (36)
Geraldton
Boundary of
Agricultural Area
Merredin
PERTH
Bunbury
Esperance
Albany
N
0
100
200 Km

Appendix 64. Locations of 2001-2010 November Wetlands (94)





Appendix 65. Locations of all wetlands (n=52) monitored in all Septembers of 1981-1990 <u>and</u> 2001-2010.



Appendix 66. Locations of all wetlands (n=52) monitored in all Novembers of 1981-1990 and 2001-2010.

Appendix 67. Wetlands in each time series.

#	Code	Wetland	Sep 1981-90	Sep 1981-00	Sep 1981-10	Sep 1991-00	Sep 1991-10	Sep 2001-10	Nov 1981-90	Nov 1981-00	Nov 1981-10	Nov 1991-00	Nov 1991-10	Nov 2001-10	Total
		No. of Wetlands	**65**	**21**	**21**	**28**	**27**	**90**	**69**	**28**	**28**	**36**	**36**	**94**	
		Period (Years)	**10**	**20**	**30**	**10**	**20**	**10**	**10**	**20**	**30**	**10**	**20**	**10**	
1	ALB1	ALBANY 26385						X						X	2
2	ALTH	ALTHAM	X					X	X					X	4
3	ANDE	ANDERSON	X					X	X					X	4
4	ARDA	ARDATH						X						X	2
5	ATKI	ATKINS YATE						X							1
6	BAMB	BAMBUN						X	X					X	3
7	BENN	BENNETTS												X	1
8	BEVE	BEVERLEY				X	X	X	X	X	X	X	X	X	9
9	BLUE	BLUE GUM						X						X	2
10	BOA1	BOAT HARBOUR LAKE 1						X						X	2
11	BOYU	BOYUP BROOK 18239	X					X	X	X	X	X	X	X	8
12	BROA	BROADWATER						X						X	2
13	BROW	BROWN	X					X	X					X	4
14	BRYD	BRYDE	X	X	X	X	X	X	X	X	X	X	X	X	12
15	BYEN	BYENUP	X					X	X					X	4
16	CAMP	CAMPION	X					X	X					X	4
17	CASU	CASUARINA	X	X	X	X	X	X	X	X	X	X	X	X	12
18	CHAN	CHANDALA				X			X	X	X	X	X	X	7
19	CLIF	CLIFTON						X				X	X	X	4
20	CMBG	COOMALBIDGUP												X	1
21	COBL	COBLININE	X						X						2
22	COLL	COLLETS ROAD SWAMP												X	1
23	COOM	COOMELBERRUP						X						X	2
24	CORR	CORRIGIN 12900				X	X	X				X	X	X	6
25	COYR	COYRECUP	X	X	X	X	X	X	X	X	X	X	X	X	12
26	CRAC	CRACKERS	X	X	X	X	X	X	X	X	X	X	X	X	12
27	DAVI	DAVIES						X						X	2
28	DOBA	DOBADERRY	X	X	X	X	X	X	X					X	8
29	DULB	DULBINNING	X	X	X	X	X	X				X	X	X	9
30	DUMB	DUMBLEYUNG	X	X	X	X	X	X	X	X	X	X	X	X	12
31	DUND	DUNDAS 33113							X						1
32	EGAN	EGANU	X	X	X	X	X	X	X					X	8
33	EGRE	EGRET						X				X	X	X	4
34	ENEM	ENEMINGA	X						X						2
35	ESP1	ESPERANCE 26410				X	X	X	X					X	5
36	ESP3	ESPERANCE 27985	X					X	X					X	4
37	FLAG	FLAGSTAFF	X					X	X					X	4
38	FORR	FORRESTDALE	X					X	X	X	X	X	X	X	8
39	FRAS	FRASERS						X						X	2
40	GIBB	GIBB ROAD						X						X	2
41	GNO1	GNOWANGERUP 26264	X						X						2
42	GOON	GOONAPING						X							1
43	GORE	GORE	X	X	X	X	X	X	X	X	X	X	X	X	12
44	GOUN	GOUNTER	X						X						2
45	GUND	GUNDARING	X						X						2
46	GURA	GURAGA				X	X	X				X	X	X	6
47	HARV	HARVEY 12632	X					X	X	X	X	X	X	X	8
48	HIND	HINDS	X					X	X					X	4
49	JAND	JANDABUP	X	X	X	X	X	X						X	7
50	JASP	JASPER				X	X	X						X	4
51	JERD	JERDACUTTUP	X	X	X	X	X	X	X	X	X	X	X	X	12
52	JOON	JOONDALUP	X	X	X	X	X	X	X					X	8
53	KENT	KENT 29020						X						X	2
54	KOND	KONDININ	X						X						2
55	KWOB	KWOBRUP	X						X						2
56	KWOR	KWORNICUP	X					X	X	X	X	X	X	X	8

Note: For coordinates and other details of each wetland, refer to Table 1 of Lane *et al.* (2015).

Appendix 67 continued. Wetlands in each time series.

#	Code	Wetland	Sep 1981-90	Sep 1981-00	Sep 1981-10	Sep 1991-00	Sep 1991-10	Sep 2001-10	Nov 1981-90	Nov 1981-00	Nov 1981-10	Nov 1991-00	Nov 1991-10	Nov 2001-10	Total
		No. of Wetlands	65	21	21	28	27	90	69	28	28	36	36	94	
		Period (Years)	10	20	30	10	20	10	10	20	30	10	20	10	
57	LITT	LITTLE WHITE	X					X						X	3
58	LOGU	LOGUE	X	X	X	X	X	X	X	X	X	X	X	X	12
59	MARI	MARINGUP												X	1
60	MART	MARTINUP	X					X	X					X	4
61	MCLA	MCLARTY						X						X	2
62	MEAR	MEARS						X	X					X	3
63	METT	METTLER						X				X	X	X	4
64	MOAT	MOATES	X					X	X	X	X	X	X	X	8
65	MORT	MORTIJINUP						X						X	2
66	MTMA	MOUNT MARSHALL 26687	X						X						2
67	MUIR	MUIR	X					X	X	X	X	X	X	X	8
68	NGOP	NGOPITCHUP						X						X	2
69	NINA	NINAN	X					X	X					X	4
70	NINE	NINE MILE	X					X	X	X	X	X	X	X	8
71	NOOB	NOOBIJUP						X						X	2
72	NOON	NOONYING	X						X					X	3
73	NPAR	NORTH PARRIUP						X						X	2
74	OWIN	OWINGUP						X						X	2
75	PABE	PABELUP SOUTH						X						X	2
76	PALL	PALLARUP							X						1
77	PARK	PARKEYERRING	X					X	X					X	4
78	PINJ	PINJARREGA	X						X						2
79	PLEA	PLEASANT VIEW	X					X	X	X	X	X	X	X	8
80	POOR	POORGINUP	X					X	X					X	4
81	POWE	POWELL	X					X	X	X	X	X	X	X	8
82	RANG	RANGE ROAD YATE						X						X	2
83	REDB	RED (BRUCE ROCK)						X						X	2
84	REDM	RED (MANJIMUP)							X						1
85	RONN	RONNERUP						X						X	2
86	SHAR	SHARK	X	X	X	X	X	X	X	X	X	X	X	X	12
87	SHAS	SHASTER	X						X						2
88	STAT	STATION	X	X	X	X	X	X	X	X	X	X	X	X	12
89	STRE	STREETS							X						1
90	TAAR	TAARBLIN SOUTH	X	X	X	X	X	X						X	7
91	THOM	THOMSONS	X	X	X	X	X	X	X	X	X	X	X	X	12
92	TOOL	TOOLIBIN	X					X						X	3
93	TORD	TORDIT-GURRUP	X						X					X	3
94	TOWE	TOWERINNING	X					X	X	X	X	X	X	X	8
95	UNIC	UNICUP	X					X	X	X	X	X	X	X	8
96	VARL	VARLEY	X					X	X					X	4
97	WALB	WALBYRING	X	X	X	X	X	X				X	X	X	9
98	WALY	WALYORMOURING	X					X	X					X	4
99	WANN	WANNAMAL	X	X	X	X	X	X	X	X	X	X	X	X	12
100	WARD	WARDEN	X	X	X	X	X	X	X	X	X	X	X	X	12
101	WARG	WARDERING	X						X						2
102	WARR	WARRINUP	X					X	X	X	X	X	X	X	8
103	WEST	WEST ARTHUR 5456	X					X	X					X	4
104	WHEA	WHEATFIELD						X						X	2
105	WHIN	WHITE (NARROGIN)						X						X	2
106	WHIW	WHITE WATER	X					X	X					X	4
107	WILS	WILSON						X						X	2
108	YAAL	YAALUP				X	X	X						X	4
109	YARN	YARNUP	X					X	X	X	X	X	X	X	8
110	YARR	YARRA YARRA						X						X	2
111	YEAL	YEALERING	X	X	X	X	X	X	X						7
112	YELL	YELLILUP						X				X	X	X	4
113	YURI	YURINE							X						1

Appendix 68a. Wetlands in each September time series and corresponding rainfall recording (BoM) stations.

	September Wetlands and Rainfall Stations											
	1981-1990		1981-2000		1981-2010		1991-2000		1991-2010		2001-2010	
	10 year period		20 year period		30 year period		10 year period		20 year period		10 year period	
	65 wetlands		21 wetlands		21 wetlands		28 wetlands		27 wetlands		90 wetlands	
#	Wetland	BoM Station	Wetland	BoM Station	Wetland	BoM Station	Wetland	BoM Station	Wetland	BoM Station	Wetland	BoM Station
1	ALTH	10595	BRYD	10692	BRYD	10692	BEVE	10524	BEVE	10524	ALB1	9848
2	ANDE	10694	CASU	10508	CASU	10508	BRYD	10692	BRYD	10692	ALTH	10595
3	BOYU	9668	COYR	10508	COYR	10508	CASU	10508	CASU	10508	ANDE	10694
4	BROW	10662	CRAC	9144	CRAC	9144	CHAN	9024	CORR	10668	ARDA	10118
5	BRYD	10692	DOBA	10795	DOBA	10795	CORR	10668	COYR	10508	ATKI	10611
6	BYEN	9506	DULB	10654	DULB	10654	COYR	10508	CRAC	9144	BAMB	9024
7	CAMP	10112	DUMB	10704	DUMB	10704	CRAC	9144	DOBA	10795	BEVE	10524
8	CASU	10508	EGAN	8037	EGAN	8037	DOBA	10634	DULB	10654	BLUE	8008
9	COBL	10704	GORE	9626	GORE	9626	DULB	10654	DUMB	10704	BOA1	9647
10	COYR	10508	JAND	9021	JAND	9021	DUMB	10704	EGAN	8037	BOYU	9668
11	CRAC	9144	JERD	9557	JERD	9957, 9961	EGAN	8037	ESP1	9955	BROA	9909
12	DOBA	10634	JOON	9021	JOON	9021	ESP1	9955	GORE	9626	BROW	10534, 10662
13	DULB	10654	LOGU	8225	LOGU	8225	GORE	9822	GURA	9144	BRYD	10692
14	DUMB	10704	SHAR	9789	SHAR	9789	GURA	9144	JAND	9021	BYEN	9506
15	EGAN	8037	STAT	9789	STAT	9789	JAND	9021	JASP	9592	CAMP	10112
16	ENEM	9054	TAAR	10561	TAAR	10561	JASP	9592	JERD	9957, 9961	CASU	10508
17	ESP3	12265	THOM	9064	THOM	9064	JERD	9557	JOON	9021	CLIF	9614
18	FLAG	10544	WALB	10654	WALB	10654	JOON	9021	LOGU	8225	COOM	10831
19	FORR	9172	WANN	8159	WANN	8159	LOGU	8225	SHAR	9789	CORR	10668
20	GNO1	9837	WARD	9789	WARD	9789	SHAR	9789	STAT	9789	COYR	10508
21	GORE	9626	YEAL	10662	YEAL	10534, 10662	STAT	9789	TAAR	10561	CRAC	9144
22	GOUN	10513					TAAR	10561	THOM	9064	DAVI	9547
23	GUND	10704					THOM	9064	WALB	10654	DOBA	10795
24	HARV	9614					WALB	10654	WANN	8159	DULB	10654
25	HIND	8070					WANN	8159	WARD	9789	DUMB	10704
26	JAND	9021					WARD	9789	YAAL	10595	EGAN	8037
27	JERD	9557					YAAL	10595	YEAL	10662, 10534	EGRE	9657
28	JOON	9021					YEAL	10662			ESP1	9955
29	KOND	10668									ESP3	12265
30	KWOB	10508									FLAG	10544
31	KWOR	9561									FORR	9172
32	LITT	10561									FRAS	10042
33	LOGU	8225									GIBB	9172
34	MART	10544									GOON	10795
35	MOAT	9930									GORE	9626
36	MTMA	10007									GURA	9144
37	MUIR	9506									HARV	9614
38	NINA	8137									HIND	8070
39	NINE	9614									JAND	9021
40	NOON	10121									JASP	9592
41	PARK	10647									JERD	9961
42	PINJ	8037									JOON	9021
43	PLEA	9633									KENT	10692
44	POOR	9506									KWOR	9561
45	POWE	9551									LITT	10561
46	SHAR	9789									LOGU	8225
47	SHAS	9955									MART	10544
48	STAT	9789									MCLA	9614
49	TAAR	10561									MEAR	10628
50	THOM	9064									METT	9754
51	TOOL	10654									MOAT	9930
52	TORD	9506									MORT	9822
53	TOWE	9862									MUIR	9506
54	UNIC	9673									NGOP	10866
55	VARL	10565									NINA	8137
56	WALB	10654									NINE	9614
57	WALY	10250									NOOB	9506
58	WANN	8159									NPAR	9955
59	WARD	9789									OWIN	9784
60	WARG	10531									PABE	10792
61	WARR	9740									PARK	10647
62	WEST	10641									PLEA	9633
63	WHIW	10534									POOR	9506
64	YARN	9506									POWE	9551
65	YEAL	10662									RANG	10595
66											REDB	10807
67											RONN	10611
68											SHAR	9789
69											STAT	9789
70											TAAR	10561
71											THOM	9064
72											TOOL	10654
73											TOWE	9862
74											UNIC	9673
75											VARL	10565
76											WALB	10654
77											WALY	10250
78											WANN	8159
79											WARD	9789
80											WARR	9740
81											WEST	10641
82											WHEA	9789
83											WHIN	10561
84											WHIW	10534
85											WILS	9592
86											YAAL	10595
87											YARN	9506
88											YARR	8121
89											YEAL	10534, 10662
90											YELL	9835

Notes: for details of each of these Bureau of Meteorology (BoM) rainfall recording stations, refer to www.bom.gov.au

Appendix 68b. Wetlands in each November time series and corresponding rainfall recording (BoM) stations.

	November Wetlands and Rainfall Stations											
	1981-1990		1981-2000		1981-2010		1991-2000		1991-2010		2001-2010	
	10 year period		20 year period		30 year period		10 year period		20 year period		10 year period	
	69 wetlands		28 wetlands		28 wetlands		36 wetlands		36 wetlands		94 wetlands	
#	Wetland	BoM Station	Wetland	BoM Station	Wetland	BoM Station	Wetland	BoM Station	Wetland	BoM Station	Wetland	BoM Station
1	ALTH	10595	BEVE	10524	BEVE	10524	BEVE	10524	BEVE	10524	ALB1	9848
2	ANDE	10694	BOYU	9668	BOYU	9668	BOYU	9668	BOYU	9668	ALTH	10595
3	BAMB	9024	BRYD	10692	BRYD	10692	BRYD	10692	BRYD	10692	ANDE	10694
4	BEVE	10524	CASU	10508	CASU	10508	CASU	10508	CASU	10508	ARDA	10118
5	BOYU	9668	CHAN	9024	CHAN	9024	CHAN	9024	CHAN	9024	BAMB	9024
6	BROW	10662	COYR	10508	COYR	10508	CLIF	9614	CLIF	9614	BENN	10878
7	BRYD	10692	CRAC	9144	CRAC	9144	CORR	10668	CORR	10668	BEVE	10524
8	BYEN	9506	DUMB	10704	DUMB	10704	COYR	10508	COYR	10508	BLUE	8008
9	CAMP	10112	FORR	9172	FORR	9172	CRAC	9144	CRAC	9144	BOA1	9647
10	CASU	10508	GORE	9626	GORE	9626	DULB	10654	DULB	10654	BOYU	9668
11	CHAN	9024	HARV	9614	HARV	9614	DUMB	10704	DUMB	10704	BROA	9909
12	COBL	10704	JERD	9557, 9961	JERD	9557, 9961	EGRE	9657	EGRE	9657	BROW	10534, 10662
13	COYR	10508	KWOR	9561	KWOR	9561	FORR	9172	FORR	9172	BRYD	10692
14	CRAC	9144	LOGU	8225	LOGU	8225	GORE	9626	GORE	9626	BYEN	9506
15	DOBA	10634	MOAT	9930	MOAT	9930	GURA	9144	GURA	9144	CAMP	10112
16	DUMB	10704	MUIR	9506	MUIR	9506	HARV	9614	HARV	9614	CASU	10508
17	DUND	12077	NINE	9614	NINE	9614	JERD	9557	JERD	9557, 9961	CHAN	9024
18	EGAN	8037	PLEA	9633	PLEA	9633	KWOR	9561	KWOR	9561	CLIF	9614
19	ENEM	9054	POWE	9551	POWE	9551	LOGU	8225	LOGU	8225	CMBG	9772
20	ESP1	9955	SHAR	9789	SHAR	9789	METT	9754	METT	9754	COLL	9835
21	ESP3	12265	STAT	9789	STAT	9789	MOAT	9930	MOAT	9930	COOM	10831
22	FLAG	10544	THOM	9064	THOM	9064	MUIR	9506	MUIR	9506	CORR	10668
23	FORR	9172	TOWE	9862	TOWE	9862	NINE	9614	NINE	9614	COYR	10508
24	GNO1	9837	UNIC	9673	UNIC	9673	PLEA	9633	PLEA	9633	CRAC	9144
25	GORE	9626	WANN	8159	WANN	8159	POWE	9551	POWE	9551	DAVI	9518
26	GOUN	10513	WARD	9789	WARD	9789	SHAR	9789	SHAR	9789	DOBA	10795
27	GUND	10704	WARR	9740	WARR	9740	STAT	9789	STAT	9789	DULB	10654
28	HARV	9614	YARN	9506	YARN	9506	THOM	9064	THOM	9064	DUMB	10704
29	HIND	8070					TOWE	9862	TOWE	9862	EGAN	8037
30	JERD	9557					UNIC	9673	UNIC	9673	EGRE	9657
31	JOON	9021					WALB	10654	WALB	10654	ESP1	9955
32	KOND	10668					WANN	8159	WANN	8159	ESP3	12265
33	KWOB	10508					WARD	9789	WARD	9789	FLAG	10544
34	KWOR	9561					WARR	9740	WARR	9740	FORR	9172
35	LOGU	8225					YARN	9506	YARN	9506	FRAS	10042
36	MART	10544					YELL	9835	YELL	9835	GIBB	9172
37	MEAR	10628									GORE	9626
38	MOAT	9930									GURA	9144
39	MTMA	10007									HARV	9614
40	MUIR	9506									HIND	8138
41	NINA	8137									JAND	9021
42	NINE	9614									JASP	9592
43	NOON	10121									JERD	9961
44	PALL	10611									JOON	9021
45	PARK	10647									KENT	10692
46	PINJ	8037									KWOR	9561
47	PLEA	9633									LITT	10561
48	POOR	9506									LOGU	8225
49	POWE	9551									MARI	9590
50	REDM	9530									MART	10544
51	SHAR	9789									MCLA	9614
52	SHAS	9955									MEAR	10628
53	STAT	9789									METT	9754
54	STRE	8008									MOAT	9930
55	THOM	9064									MORT	9822
56	TORD	9506									MUIR	9506
57	TOWE	9862									NGOP	10866
58	UNIC	9673									NINA	8137
59	VARL	10565									NINE	9614
60	WALY	10250									NOOB	9506
61	WANN	8159									NOON	10121
62	WARD	9789									NPAR	9955
63	WARG	10531									OWIN	9647
64	WARR	9740									PABE	10707
65	WEST	10641									PARK	10647
66	WHIW	10534									PLEA	9633
67	YARN	9506									POOR	9506
68	YEAL	10662									POWE	9551
69	YURI	9144									RANG	10595
70											REDB	10807
71											RONN	10878
72											SHAR	9789
73											STAT	9789
74											TAAR	10561
75											THOM	9064
76											TOOL	10654
77											TORD	9506
78											TOWE	9862
79											UNIC	9673
80											VARL	10565
81											WALB	10654
82											WALY	10250
83											WANN	8159
84											WARD	9789
85											WARR	9740
86											WEST	10641
87											WHEA	9789
88											WHIN	10561
89											WHIW	10654
90											WILS	9592
91											YAAL	10595
92											YARN	9506
93											YARR	8121
94											YELL	9835

Appendix 68c. Rainfall time series and wetlands for which rainfall data from more than one Bureau of Meteorology (BoM) recording station was used and and the periods of data used.

Series	Wetland	BoM Station #1	Start	End	BoM Station #2	Start	End
Sep 1981-2010	JERD	9557	9/1980	12/2000	9961	1/2001	8/2010
Sep 1981-2010	YEAL	10662	9/1980	12/2005	10534	1/2006	8/2010
Sep 1991-2010	JERD	9557	9/1990	12/2000	9961	1/2001	8/2010
Sep 1991-2010	YEAL	10662	9/1990	12/2005	10534	1/2006	8/2010
Sep 2001-2010	BROW	10662	9/2000	12/2005	10534	1/2006	8/2010
Sep 2001-2010	YEAL	10662	9/2000	12/2005	10534	1/2006	8/2010
Nov 1981-2010	JERD	9557	11/1980	12/2000	9961	1/2001	10/2010
Nov 1991-2010	JERD	9557	11/1990	12/2000	9961	1/2001	10/2010
Nov 2001-2010	BROW	10662	11/2000	12/2005	10534	1/2006	10/2010

Appendix 69. Wetlands, distances to rainfall recording (BoM) stations, data obtained and years in which monthly rainfall data is incomplete.

Wetland Code	Wetland	1st BoM Stn #	1st BoM Station	Distance (km)	Data obtained	Years within 1977[1]-2010 in which monthly rainfall data is incomplete	2nd BoM Stn #	2nd BoM Station	Distance (km)	Data obtained	Years within 1977[1]-2010 in which monthly rainfall data is incomplete
ALB1	Albany 26385	9848	Windrush	3.9	Y						
ALTH	Altham	10595	Pingrup South	28.6	Y	2003,2004,2005,2007					
ANDE	Anderson	10694	Twolganup	21.1	Y						
ARDA	Ardath	10118	Breakell	16.7	Y	1991,2004					
ATKI	Atkins Yate	10611	Mount Madden	17.9	Y	2001,2002,2003,2004,2006	10895	Monte Vista	37.5	Y	2009,2010
BAMB	Bambun	9024	Marbling	23.4	Y	1999,2001					
BENN	Bennetts	10878	Mount Madden	15.9	Y	2001,2002,2003,2004,2006	10879	Chesalon	28.9	Y	
BEVE	Beverley	10524	Brookton	19.7	Y	1999,2007					
BLUE	Blue Gum	8008	Berkshire Valley	15.8	Y						
BOA1	Boat Harbour	9647	Wereroa	18.5	Y	2003					
BOYU	Boyup Brook 18239	9668	Kuranda	16.9	Y	2003,2004,2005,2007					
BROA	Broadwater	9909	Aston Downs	14	Y	1995,1998,2003					
BROW	Brown	10662	Yealering	4.2	Y	2006,2007,2008,2009,2010	10534	Colorado	10.5	Y	2001,2002,2003,2004, 2005
BRYD	Bryde	10692	Newdegate Research Station	26.6	Y	2008,2010					
BYEN	Byenup	9506	Bangalup	16.2	Y	1977,1994,1999,2010	9843	Frankland Vineyards	23.8	Y	2001,2003,2004
CAMP	Campion	10112	Nungarin	23.1	Y	2001,2003					
CASU	Casuarina	10508	Badgebup	16.4	Y	1995,2003,2006					
CHAN	Chandala	9024	Marbling	14.1	Y	1999,2001					
CLIF	Clifton	9614	Waroona	26.8	Y	1997,2000,2001					
CMBG	Coomalbidgup	9772	Erinair	15.1	Y	2004					
COBL	Coblinine	10704	Ballaying	13.5	Y						
COLL	Collets Road Swamp	10792	Gairdner	42.2	Y	1977,1990,2000,2001, 2002,2003,2005,2006	9835	Wayjo Park	46.5	Y	2002,2003,2005,2006, 2007
COOM	Coomelberrup	10831	Glenrose	18.2	Y	2005,2007					
CORR	Corrigin 12900	10668	Koorikin	7.6	Y						
COYR	Coyrecup	10508	Badgebup	13	Y	1995,2003,2006					
CRAC	Crackers	9144	Baramba	20.1	Y	2004					
DAVI	Davies	9547	Forest Grove	17.6	Y	2000,2001,2003,2005	9518	Cape Leeuwin	19.2	Y	
DOBA	Dobaderry	10634	Redlands	19.2	Y	2003,2005,2008,2009,2010	10795	Avondale Farm	26	Y	2000,2004,2008

[1] The authors initially sought 1977-2010 rainfall data from the Bureau of Meteorology, however the period 1977-1980 was later excluded from the analyses due to the smaller number of wetlands monitored in those years and the focus on even decadal periods to 2010.

Appendix 69 continued. Wetlands, distances to rainfall recording (BoM) stations, data obtained and years in which monthly rainfall data is incomplete.

Wetland Code	Wetland	1st BoM Stn #	1st BoM Station	Distance (km)	Data obtained	Years within 1977-2010 in which monthly rainfall data is incomplete	2nd BoM Stn #	2nd BoM Station	Distance (km)	Data obtained	Years within 1977-2010 in which monthly rainfall data is incomplete
DULB	Dulbinning	10654	Wickepin	17.3	Y	2003					
DUMB	Dumbleyung	10704	Ballaying	8	Y						
DUND	Dundas 33113	12077	Dunno	13.4	Y	1980,1981,1982, 2002					
EGAN	Eganu	8037	Coorow	19.3	Y	1978,1979,2004,2009					
EGRE	Egret	9657	Roelands	6.6	Y						
ENEM	Eneminga	9054	Tambrey	25.9	Y	2002, 2003					
ESP1	Esperance 26410	9955	Newleigh	3.5	Y	1999,2001,2002,2008					
ESP3	Esperance 27985	12265	Circle Valley	32	Y	2005,2007					
FLAG	Flagstaff	10544	Dellyanine	19.9	Y	2009,2010					
FORR	Forrestdale	9172	Jandakot Aero	8	Y	1977,1992,1993,2000	9137	Cardup	12.8	Y	2004,2005
FRAS	Frasers	10042	Dowerin	7.7	Y	2000,2001,2002					
GIBB	Gibb Road	9172	Jandakot Aero	7	Y	1977,1992,1993,2008					
GNO1	Gnowangerup 26264	9837	Wellstead	18.7	Y	2001,2003,2007,2008					
GOON	Goonaping	10634	Redlands	24.3	Y	2003,2005,2008,2009,2010	10795	Avondale Farm	25.7	Y	
GORE	Gore	9822	Dalyup park	3.5	Y	1998,2002,2003,2004,2007	9626	Pleasant Valley	6.5	Y	2003,2007
GOUN	Gounter	10513	Bendering	2.3	Y	2003,2007					
GUND	Gundaring	10704	Ballaying	6.3	Y						
GURA	Guraga	9144	Baramba	25.1	Y	2004					
HARV	Harvey 12632	9614	Waroona	21.5	Y	1997,2000,2001					
HIND	Hinds	8070	Lake Hinds	4.8	Y	2004,2005,2007,2008	8138	Wongon Hills Res. Station	19.1	Y	1999
JAND	Jandabup	9021	Perth Airport	23.3	Y						
JASP	Jasper	9592	Pemberton	32.2	Y	1999,2006					
JERD	Jerdacuttup	9557	Hopetoun	12.4	Y	2000,2001,2004,2006, 2007,2008,2009,2010	9961	Hopetoun North (1996 on)	12	Y	2000
JOON	Joondalup	9021	Perth Airport	23.5	Y						
KENT	Kent 29020	10692	Newdegate Research Station	27.8	Y	2008,2010					
KOND	Kondinin	10668	Koorikin	5.3	Y						
KWOB	Kwobrup	10508	Badgebup	12.5	Y	1995,2003,2006					
KWOR	Kwornicup	9561	Kendenup	20.3	Y	2004					
LITT	Little White	10561	Rushy Pool	5.4	Y	2003,2004					
LOGU	Logue	8225	Eneabba	12.6	Y	2006					
MARI	Maringup	9590	Northcliffe	23.5	y	1999,2000,2003,2007					

Appendix 69 continued. Wetlands, distances to rainfall recording (BoM) stations, data obtained and years in which monthly rainfall data is incomplete.

Wetland Code	Wetland	1st BoM Stn #	1st BoM Station	Distance (km)	Data obtained	Years within 1977-2010 in which monthly rainfall data is incomplete	2nd BoM Stn #	2nd BoM Station	Distance (km)	Data obtained	Years within 1977-2010 in which monthly rainfall data is incomplete
MART	Martinup	10544	Dellyanine	16.7	Y	2009,2010					
MCLA	McLarty	9614	Waroona	23.5	Y	1997,2000,2001					
MEAR	Mears	10628	Quairading	24.9	Y	1991,2000					
METT	Mettler	9754	Mettler	4.2	Y	1998,2003					
MOAT	Moates	9930	Tamaru	9.8	Y	2001,2002,2004,2005, 2007,2008	9633	Tamar	9.9	Y	1999,2001,2002,2003, 2004
MORT	Mortijinup	9822	Dalyup park	7.8	Y	1998,2002,2003,2004, 2007	9626	Pleasant Valley	11.8	Y	2003,2007
MTMA	Mount Marshall 26687	10007	Bencubbin	24.2	Y	1998,1999					
MUIR	Muir	9506	Bangalup	21.2	Y	1977,1994,1999,2010					
NGOP	Ngopitchup	10866	Cranham	3.2	Y						
NINA	Ninan	8137	Wongon Hills	9.1	Y	1999					
NINE	Nine Mile	9614	Waroona	16.8	Y	1997,2000,2001					
NOOB	Noobijup	9506	Bangalup	13.2	Y	1977,1994,1999,2010					
NOON	Noonying	10121	Tammin	3.9	Y						
NPAR	North Parriup	9955	Newleigh	30.7	Y	1999,2001,2002,2008					
OWIN	Owingup	9784	Kimberley	10.7	Y	1999,2001,2002,2003,2004	9647	Wereroa	18.8	Y	2003
PABE	Pabelup South	10792	Gairdner	46.5	Y	1977,1990,2000,2001, 2002,2003,2005,2006	10707	Jerramungup	52.1	Y	2002,2003,2005
PALL	Pallarup	10611	Mount Madden	7.9	Y	2001,2002,2003,2004,2006	10895	Monte Vista	26.9	Y	2009,2010
PARK	Parkeyerring	10647	Wagin	7.4	Y	2001,2009					
PINJ	Pinjarrega	8037	Coorow	25.4	Y	1978,1979,2004,2009					
PLEA	Pleasant View	9633	Tamar	7.7	Y	1999,2001,2002,2003,2004	9848	Windrush	7.9	Y	
POOR	Poorginup	9506	Bangalup	18.1	Y	1977,1999,2010					
POWE	Powell	9551	Grassmere	1.6	Y	2003,2004,2005,2006,2007	9741	Albany Airport	9.9	Y	2003,2007,2009
RANG	Range Road Yate	10595	Pingrup South	22	Y	2003,2004,2005,2007					
REDB	Red (Bruce Rock)	10807	Bilbarin	11.4	Y	1977,1994,1999,2000, 2001,2003	10118	Breakell	23.6	Y	1991,2004
REDM	Red (Manjimup)	9530	Deeside	23.1	Y	1994,2010					
RONN	Ronnerup	10611	Mount Madden	14.5	Y	2001,2002,2003,2004,2006	10878	Chesalon	31.9	Y	
SHAR	Shark	9789	Esperance	7.5	Y	2001					
SHAS	Shaster	9955	Newleigh	25.7	Y	1999,2001,2002,2008					
STAT	Station	9789	Esperance	5.9	Y	2001					
STRE	Streets	8008	Berkshire Valley	14.5	Y						

Appendix 69 continued. Wetlands, distances to rainfall recording (BoM) stations, data obtained and years in which monthly rainfall data is incomplete.

Wetland Code	Wetland	1st BoM Stn #	1st BoM Station	Distance (km)	Data obtained	Years within 1977-2010 in which monthly rainfall data is incomplete	2nd BoM Stn #	2nd BoM Station	Distance (km)	Data obtained	Years within 1977-2010 in which monthly rainfall data is incomplete
TAAR	Taarblin South	10561	Rushy Pool	15.7	Y	2002,2003					
THOM	Thomsons	9064	Kwinana BP Refinery	9.8	Y						
TOOL	Toolibin	10654	Wickepin	18.9	Y	2003					
TORD	Tordit-Gurrup	9506	Bangalup	17.4	Y	1977,1999,2010					
TOWE	Towerrinning	9862	Capercup	9.7	Y	2001					
UNIC	Unicup	9673	Bokerup	17.3	Y	2001,2002,2003,2004,2009	9508	Bangalup	22.7	Y	1977,1999,2010
VARL	Varley	10565	Holt Rock	4.5	Y						
WALB	Walbyring	10654	Wickepin	19.5	Y	2003					
WALY	Walyormouring	10250	Redwing	4.8	Y						
WANN	Wannamal	8159	Maysboro	32.1	Y	2000					
WARD	Warden	9789	Esperance	1.4	Y	2001					
WARG	Wardering	10531	Cherry Tree	19.9	Y	1999,2004					
WARR	Warrinup	9740	Gordon River	10.7	Y	2003,2004					
WEST	West Arthur 5456	10641	Maybrook	15	Y						
WHEA	Wheatfield	9789	Esperance	4.4	Y	2001					
WHIN	White (Narrogin)	10561	Rushy Pool	6.6	Y	2002,2003					
WHIW	White Water	10534	Colorado	8.3	Y	2001,2002,2003,2004,2005	10654	Wickepin	29.6	Y	2003
WILS	Wilson	9592	Pemberton	29.6	Y	1999,2006					
YAAL	Yaalup	10595	Pingrup South	12.1	Y	2003,2004,2005,2007					
YARN	Yarnup	9506	Bangalup	11.7	Y	1977,1999,2010					
YARR	Yarra Yarra	8121	Three Springs	5.2	Y	1978,1998,2004,2010					
YEAL	Yealering	10662	Yealering	0.3	Y	2006,2007,2008,2009,2010	10534	Colorado	13.7	Y	2001,2002,2003,2004, 2005
YELL	Yellilup	9835	Wayjo Park	11.6	Y	2002,2003,2005,2006,2007	9520	Cape Riche	41.5	Y	1995,2002,2009
YURI	Yurine	9144	Baramba	32.3	Y	2004					

Appendix 70. Results of statistical analyses of depth and rainfall time series.

DEPTH TRENDS OVER TIME

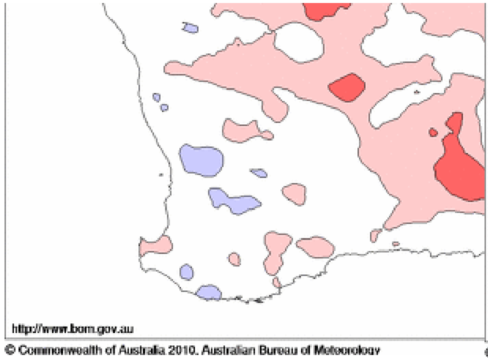
Regression model: sqrt (depth) = time (where time is number of months since January 1977)

Month	Year Group	Period	No. Wetlands	No. records	'p' value	Slope	Intercept	R-Squared	Trend	Significance	Rate of Change (mm per month)	Rate of Change (mm per Year)	SAS Program and Output filename	Comments
Sep	1981-1990	10 Year	65	650	0.5819	0.00030133	0.92358	0.0005	None				Sep81-81-90 SAS.doc	
Sep	1981-2000	20 Year	21	420	0.8402	0.00005965	1.07001	0.0001	None				Sep81-81-00 SAS.doc	
Sep	1981-2010	30 Year	21	630	0.0001	−0.00064268	1.17066	0.0228	Decreasing	Very highly significant	−1.170	−14.042	Sep81-81-10 SAS.doc	
Sep	*1980-2010*	*31 Year*	*17*	*527*	*0.0417*	*−0.0004*	*1.0543*	*0.0079*	*Decreasing*	*Significant*	*−0.689*	*−8.272*	*Sep81-80-10 SAS.doc*	*This was a late 're-analysis' of the 1981-2010 group, with 1980 added; see Section 3.8.*
Sep	1991-2000	10 Year	28	280	0.2442	−0.00109	1.3898	0.0049	None				Sep81-91-00 SAS.doc	
Sep	1991-2010	20 Year	27	540	<0.0001	−0.00146	1.46995	0.0288	Decreasing	Very highly significant	−2.566	−30.788	Sep10-91-10 SAS.doc	Outliers (JASP)
Sep	2001-2010	10 Year	90	900	0.0634	−0.00104	1.1969	0.0038	None				Sep10-01-10 SAS.doc	WHIN negative depths changed to zero. Outliers (JASP)
Nov	1981-1990	10 Year	69	690	0.1936	0.00077809	0.77987	0.0025	None				Nov81-81-90 SAS.doc	
Nov	1981-2000	20 Year	28	560	0.2836	0.00029699	0.95739	0.0021	None				Nov81-81-00 SAS.doc	Outliers (MOAT)
Nov	1981-2010	30 Year	28	840	0.0017	−0.00049253	1.07418	0.0117	Decreasing	Highly significant	−0.861	−10.328	Nov81-81-10 SAS.doc	Outliers (MOAT)
Nov	*1980-2010*	*31 Year*	*26*	*806*	*0.0688*	*−0.0003*	*1.0194*	*0.0041*	*None*				*Nov81-80-10 SAS.doc*	*This was a late 're-analysis' of the 1981-2010 group, with 1980 added; see Section 3.8.*
Nov	1991-2000	10 Year	36	360	0.0760	−0.00134	1.33681	0.0088	None				Nov81-91-00 SAS.doc	
Nov	1991-2010	20 Year	36	720	<0.0001	−0.00147	1.36444	0.0372	Decreasing	Very highly significant	−2.252	−27.030	Nov10-91-10 SAS.doc	Outliers (MOAT, YELL)
Nov	2001-2010	10 Year	94	940	0.0281	−0.00134	1.22254	0.0051	Decreasing	Significant	−1.815	−21.777	Nov10-01-10 SAS.doc	Outliers (CLIF, MOAT, DAVI, MARI, JASP)

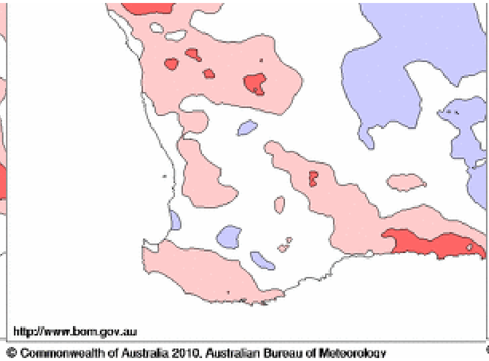
RAINFALL TRENDS OVER TIME

Regression model: totrain = time (where time is number of months since January 1977 and totrain is total rainfall for previous 12 months)

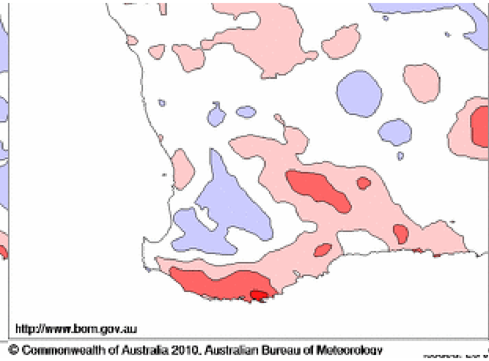
Month	Year Group	Period	No. Rainfall Stations	No. records	'p' value	Slope	Intercept	R-Squared	Trend	Significance	Rate of Change (mm per month)	Rate of Change (mm per Year)	SAS Program and Output filename	Comments
Sep	1981-1990	10 Year	65	650	0.4511	0.1627	489.87747	0.0009	None				Sep81Rain81-90 SAS.doc	Outliers (HARV, NINE, FORR)
Sep	1981-2000	20 Year	21	420	0.3855	0.10067	490.04697	0.0018	None				Sep81Rain81-00 SAS.doc	Outliers (JOON, JAND, THOM)
Sep	1981-2010	30 Year	21	630	0.0055	−0.17202	527.98649	0.0122	Decreasing	Highly significant	−0.172	−2.064	Sep81Rain81-10 SAS.doc	Outliers (JOON, JAND, THOM)
Sep	1991-2000	10 Year	28	280	0.3117	0.37753	451.31708	0.0037	None				Sep81Rain91-00 SAS.doc	Outliers (JASP, ESP1)
Sep	1991-2010	20 Year	27	540	0.0264	−0.2878	579.99086	0.0091	Decreasing	Significant	−0.288	−3.454	Sep10Rain91-10 SAS.doc	Outliers (JASP)
Sep	2001-2010	10 Year	90	900	0.0197	0.51867	314.82641	0.0060	*Increasing*	Significant	0.519	6.224	Sep10Rain01-10 SAS.doc	Outliers (JASP, WILS, BOA1)
Nov	1981-1990	10 Year	69	688	0.1738	0.29133	484.45193	0.0027	None				Nov81Rain81-90 SAS.doc	Outlier (NINE, HARV) (2 missing rainfall DUND)
Nov	1981-2000	20 Year	28	559	0.4423	−0.09537	624.38112	0.0011	None				Nov81Rain81-00 SAS.doc	Outlier (NINE) (1 missing rainfall FORR)
Nov	1981-2010	30 Year	28	840	<0.0001	−0.28096	649.55319	0.0211	Decreasing	Very highly significant	−0.281	−3.372	Nov81Rain81-10 SAS.doc	Outliers (NINE, HARV, FORR)
Nov	1991-2000	10 Year	36	360	0.1493	−0.46146	701.38273	0.0058	None				Nov81Rain91-00 SAS.doc	
Nov	1991-2010	20 Year	36	720	0.0002	−0.41227	682.33404	0.0197	Decreasing	Very highly significant	−0.412	−4.947	Nov10Rain91-10 SAS.doc	
Nov	2001-2010	10 Year	94	940	0.9676	−0.0093	514.58748	0.0000	None				Nov10Rain01-10 SAS.doc	Outliers (JASP, WILS, BOA1, OWIN, MARI)



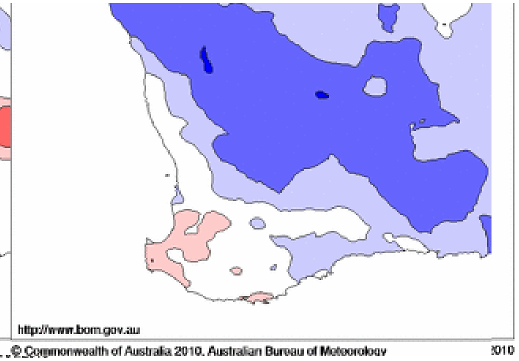
Sep 1980 – Aug 1981 Deciles



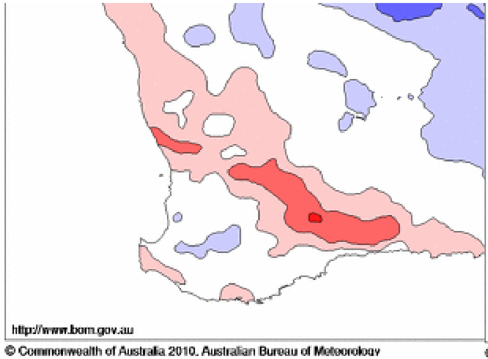
Sep 1981 – Aug 1982 Deciles



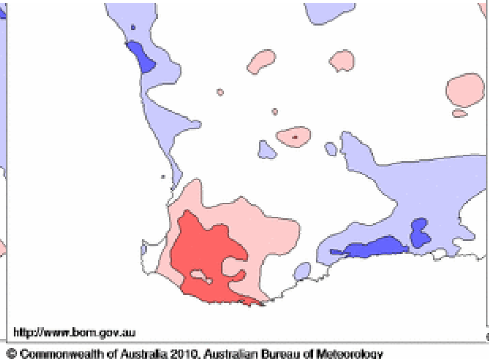
Sep 1982 – Aug 1983 Deciles



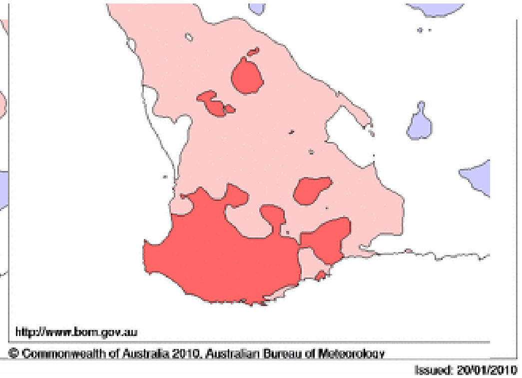
Sep 1983 – Aug 1984 Deciles



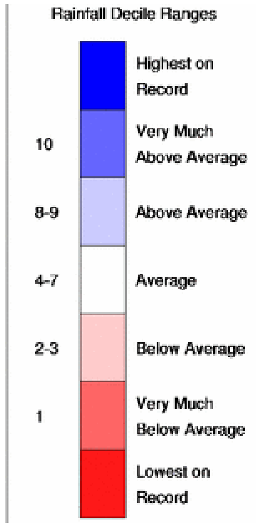
Sep 1984 – Aug 1985 Deciles

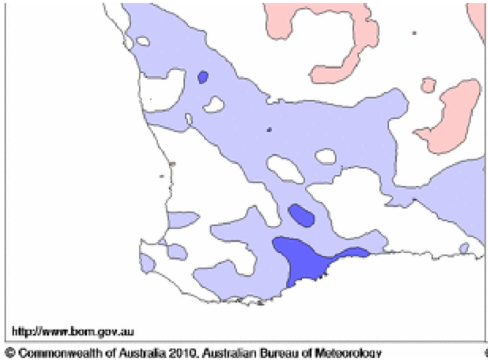


Sep 1985 – Aug 1986 Deciles

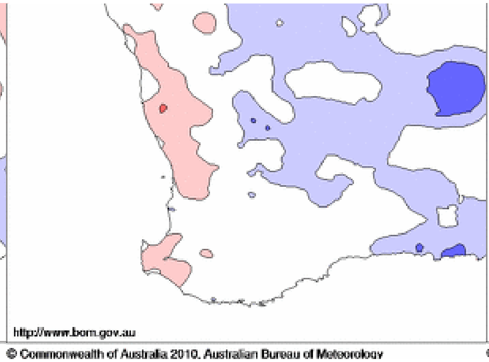


Sep 1986 – Aug 1987 Deciles

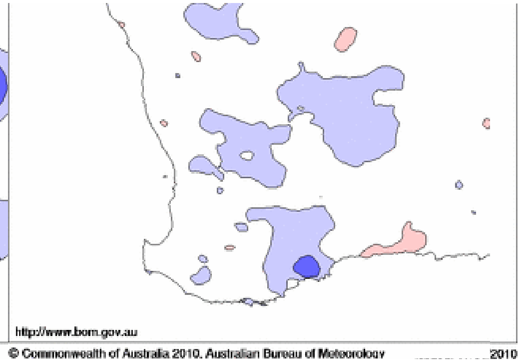




Sep 1987 – Aug 1988 Deciles



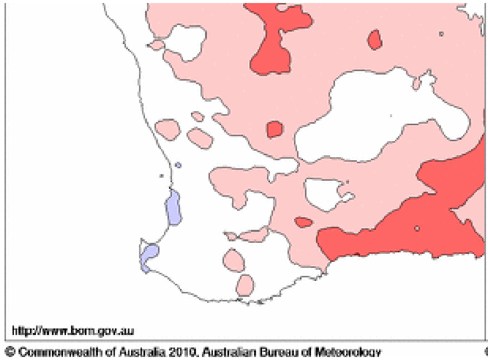
Sep 1988 – Aug 1989 Deciles



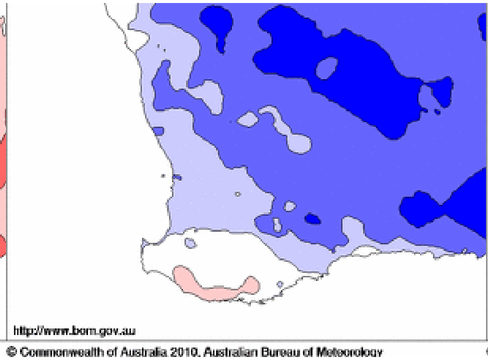
Sep 1989 – Aug 1990 Deciles

Appendix 71.

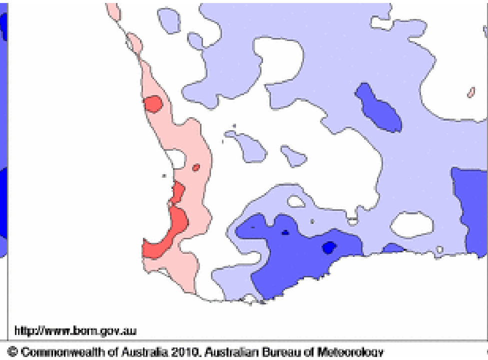
'12 months prior to Sep' rainfalls: 1981-1990.



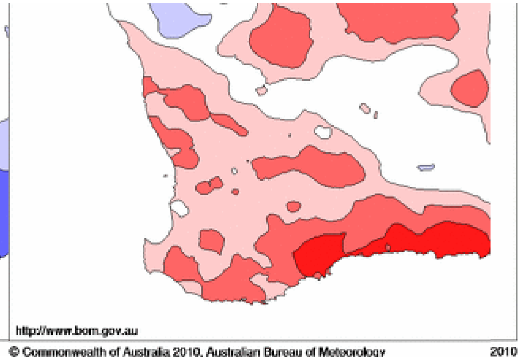
Sep 1990 – Aug 1991 Deciles



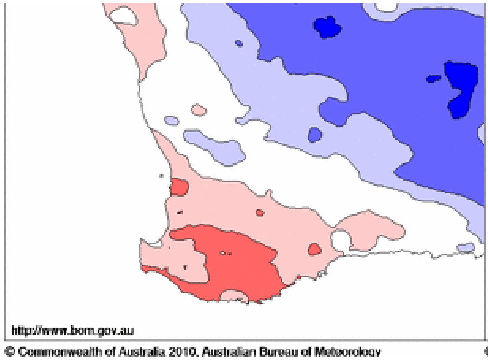
Sep 1991 – Aug 1992 Deciles



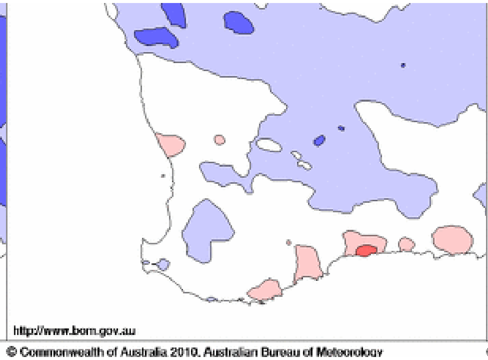
Sep 1992 – Aug 1993 Deciles



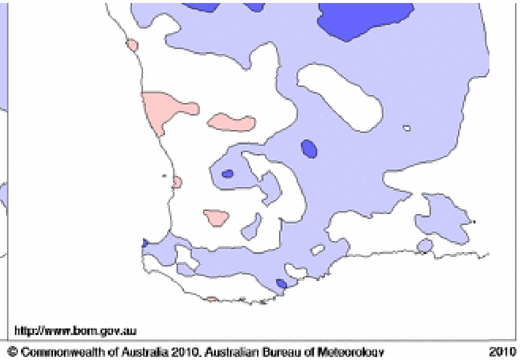
Sep 1993 – Aug 1994 Deciles



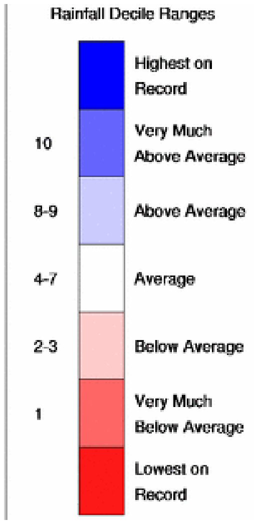
Sep 1994 – Aug 1995 Deciles

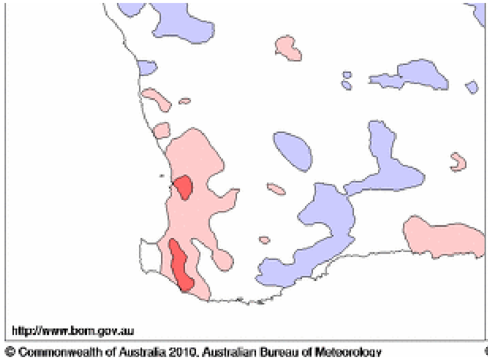


Sep 1995 – Aug 1996 Deciles

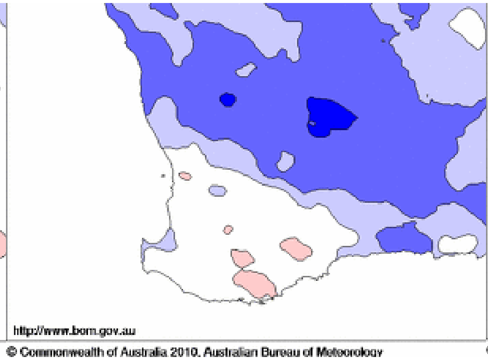


Sep 1996 – Aug 1997 Deciles

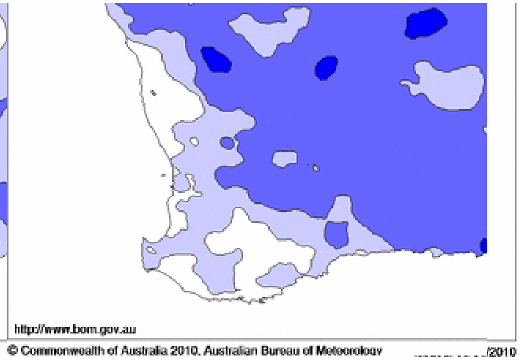




Sep 1997 – Aug 1998 Deciles



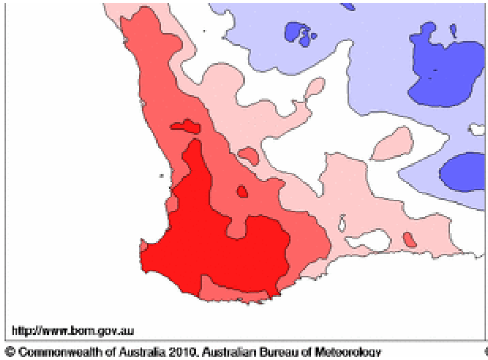
Sep 1998 – Aug 1999 Deciles



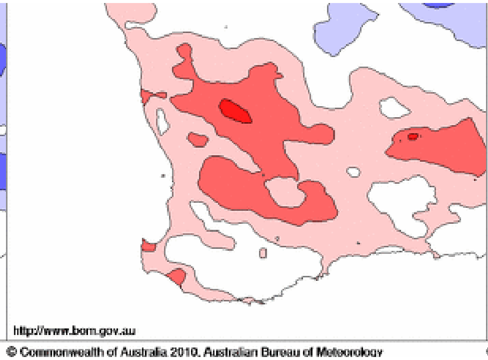
Sep 1999 – Aug 2000 Deciles

Appendix 72.

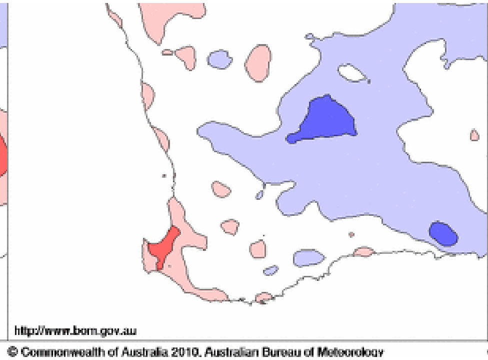
'12 months prior to Sep' rainfalls: 1991-2000.



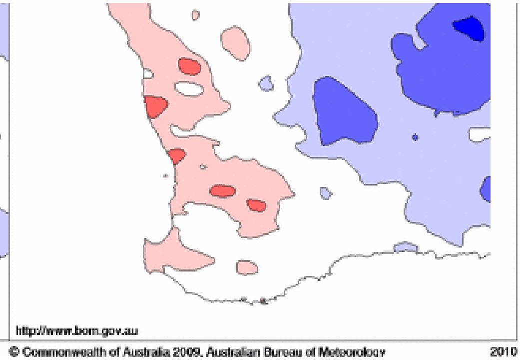
Sep 2000 – Aug 2001 Deciles



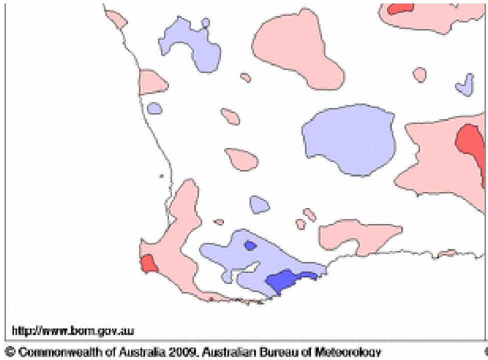
Sep 2001 – Aug 2002 Deciles



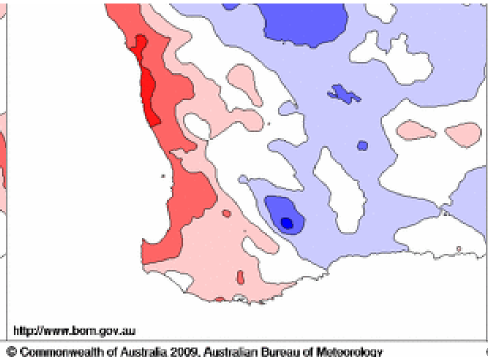
Sep 2002 – Aug 2003 Deciles



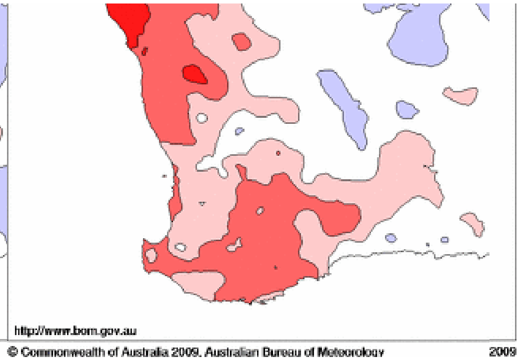
Sep 2003 – Aug 2004 Deciles



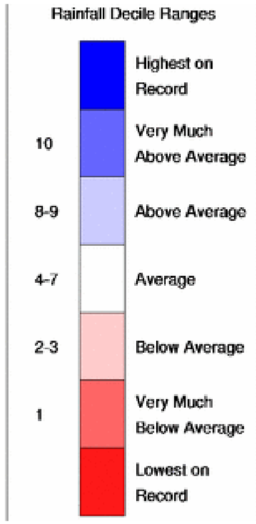
Sep 2004 – Aug 2005 Deciles

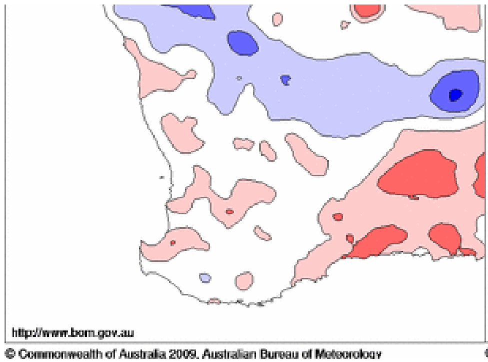


Sep 2005 – Aug 2006 Deciles

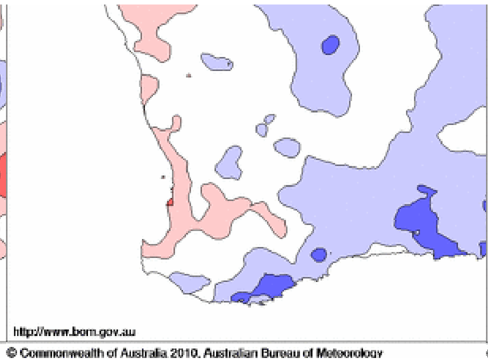


Sep 2006 – Aug 2007 Deciles

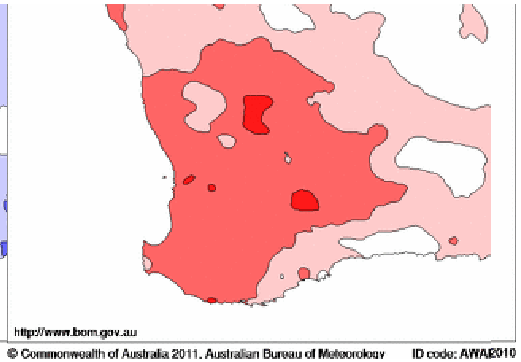




Sep 2007 – Aug 2008 Deciles



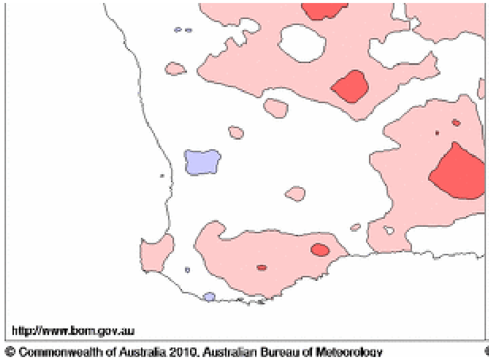
Sep 2008 – Aug 2009 Deciles



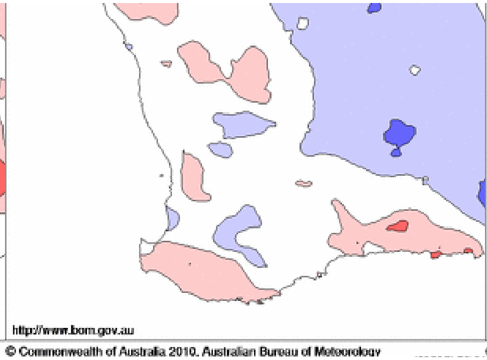
Sep 2009 – Aug 2010 Deciles

Appendix 73.

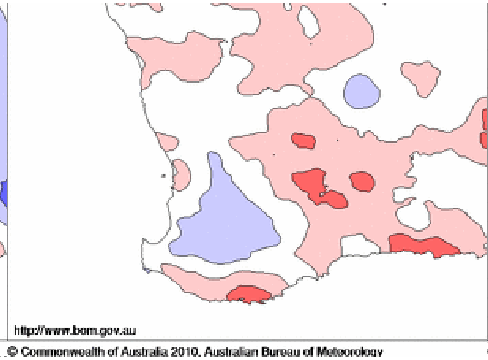
'12 months prior to Sep' rainfalls: 2001-2010.



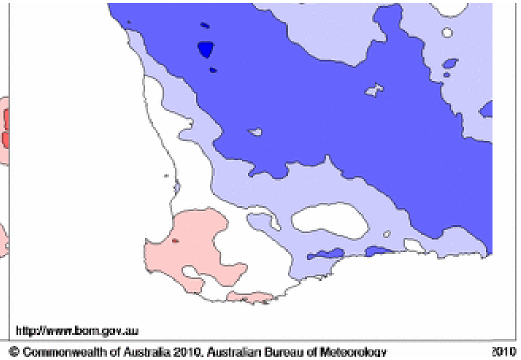
Nov 1980 – Oct 1981 Deciles



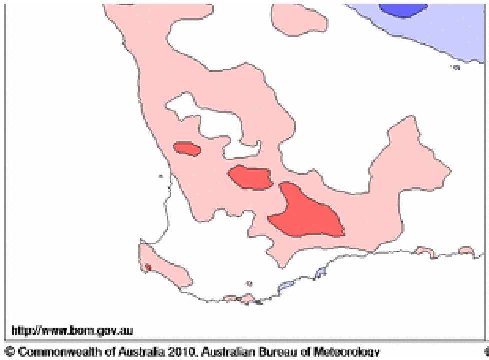
Nov 1981 – Oct 1982 Deciles



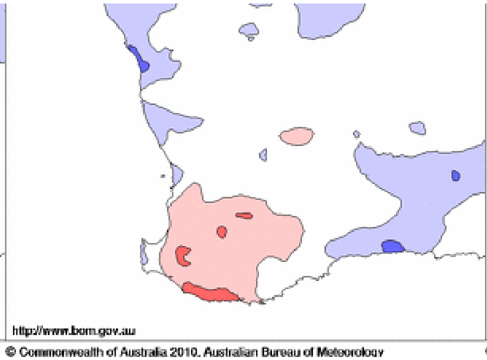
Nov 1982 – Oct 1983 Deciles



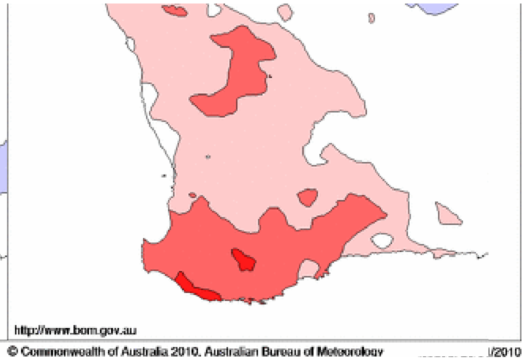
Nov 1983 – Oct 1984 Deciles



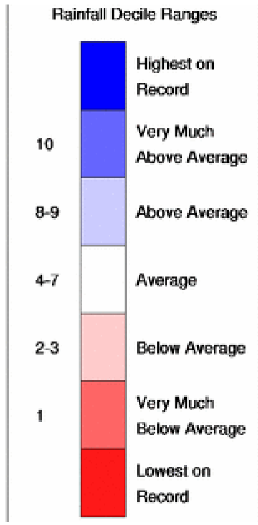
Nov 1984 – Oct 1985 Deciles

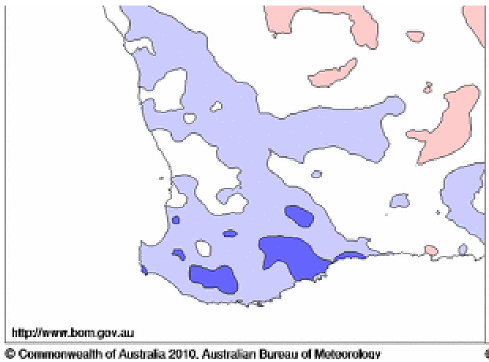


Nov 1985 – Oct 1986 Deciles

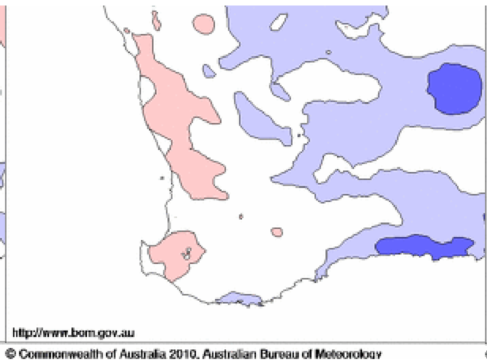


Nov 1986 – Oct 1987 Deciles

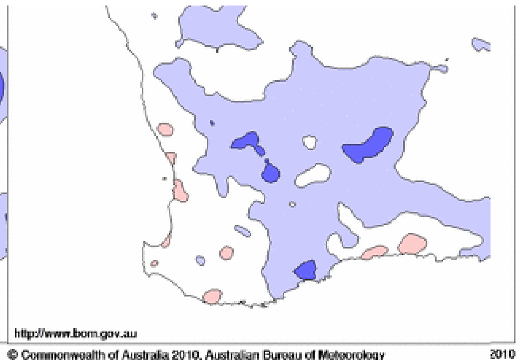




Nov 1987 – Oct 1988 Deciles



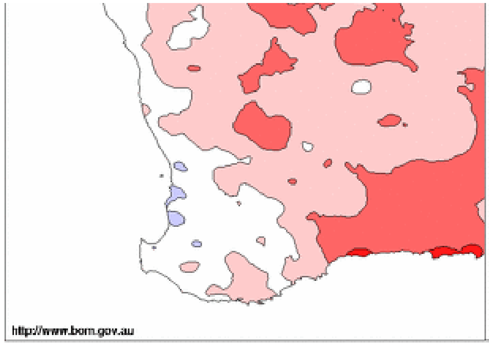
Nov 1988 – Oct 1989 Deciles



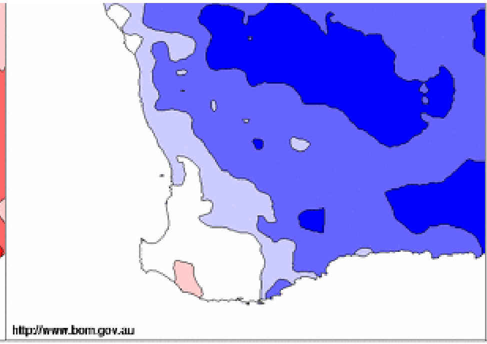
Nov 1989 – Oct 1990 Deciles

Appendix 74.

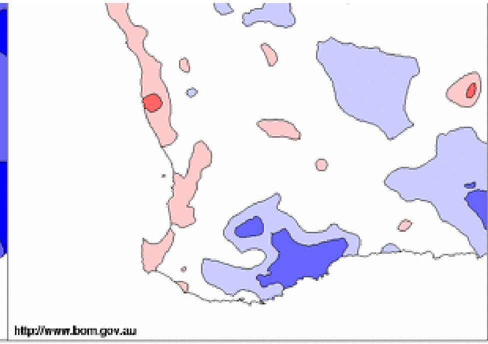
'12 months prior to Nov' rainfalls: 1981-1990.



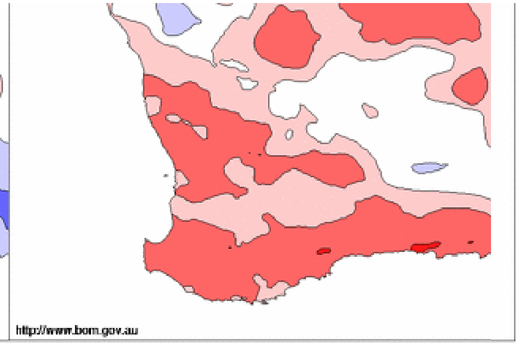
Nov 1990 – Oct 1991 Deciles



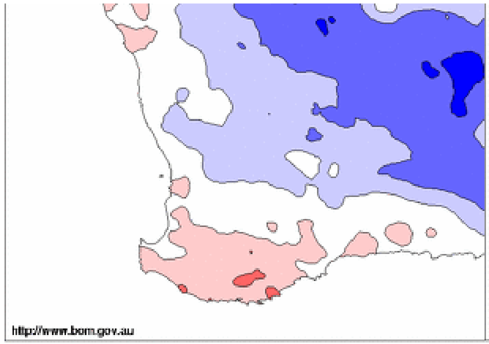
Nov 1991 – Oct 1992 Deciles



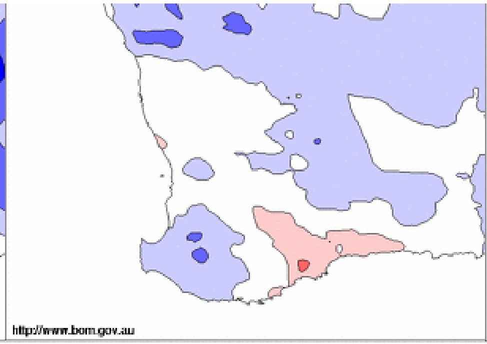
Nov 1992 – Oct 1993 Deciles



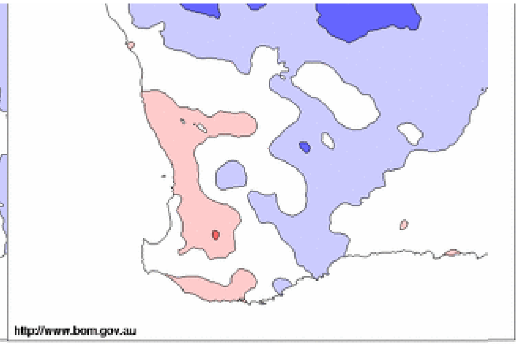
Nov 1993 – Oct 1994 Deciles



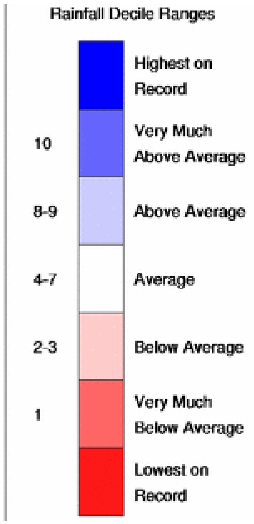
Nov 1994– Oct 1995 Deciles

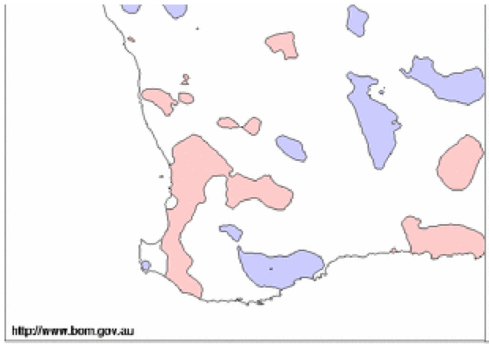


Nov 1995 – Oct 1996 Deciles

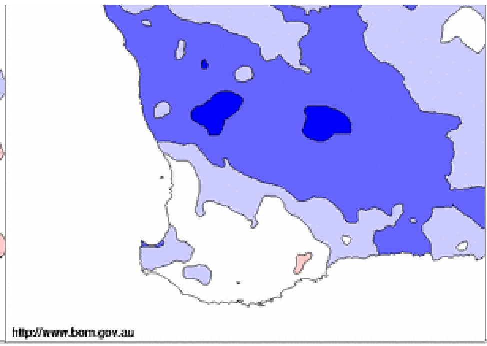


Nov 1996 – Oct 1997 Deciles

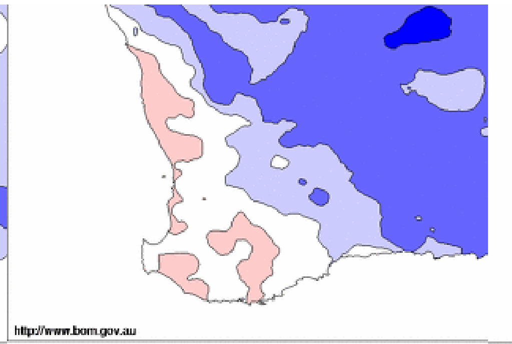




Nov 1997 – Oct 1998 Deciles



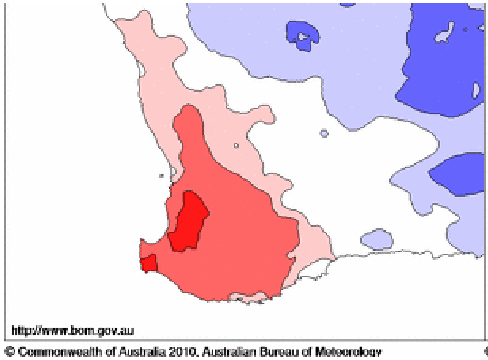
Nov 1998 – Oct 1999 Deciles



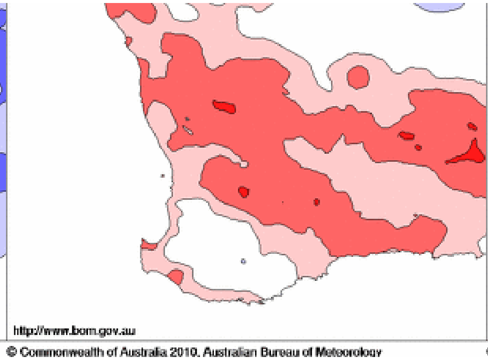
Nov 1999 – Oct 2000 Deciles

Appendix 75.

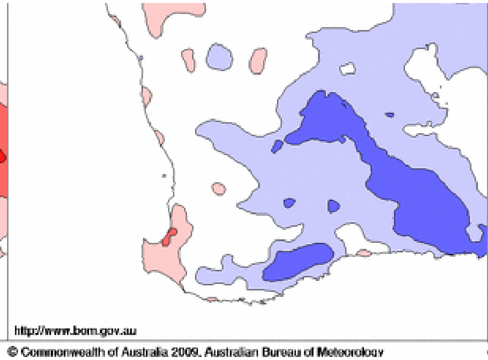
'12 months prior to Nov' rainfalls: 1991-2000.



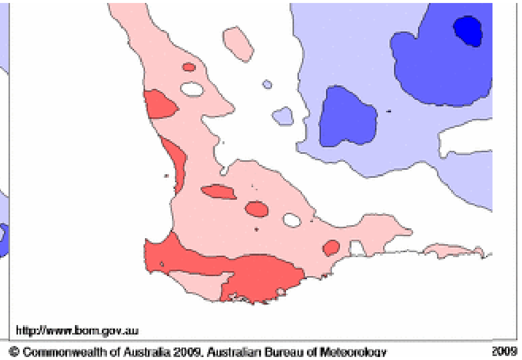
Nov 2000 – Oct 2001 Deciles



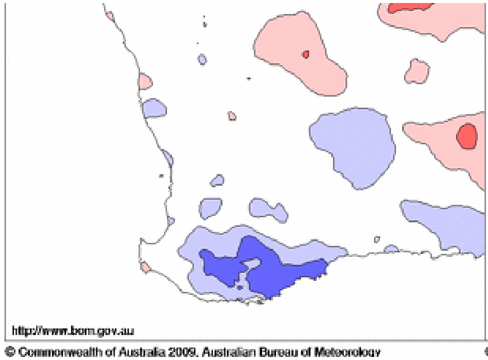
Nov 2001 – Oct 2002 Deciles



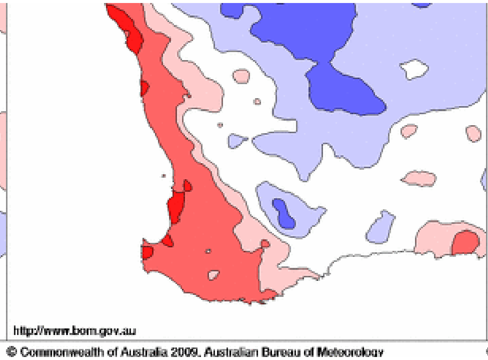
Nov 2002 – Oct 2003 Deciles



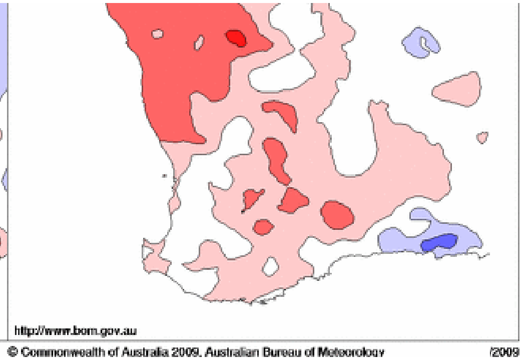
Nov 2003 – Oct 2004 Deciles



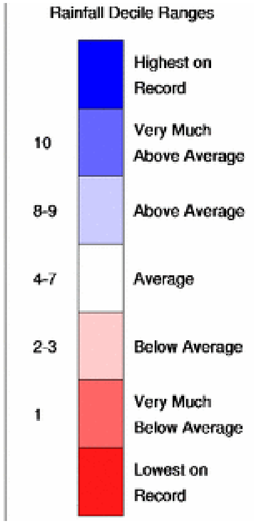
Nov 2004 – Oct 2005 Deciles

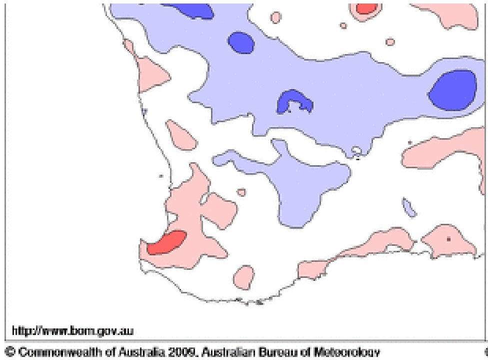


Nov 2005 – Oct 2006 Deciles

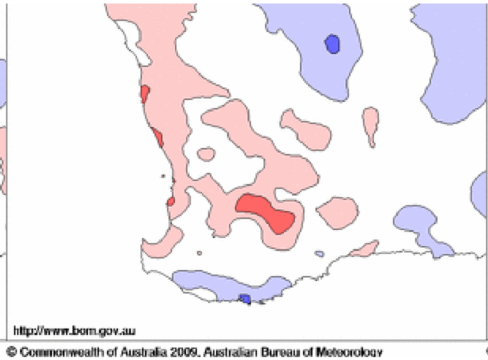


Nov 2006 – Oct 2007 Deciles

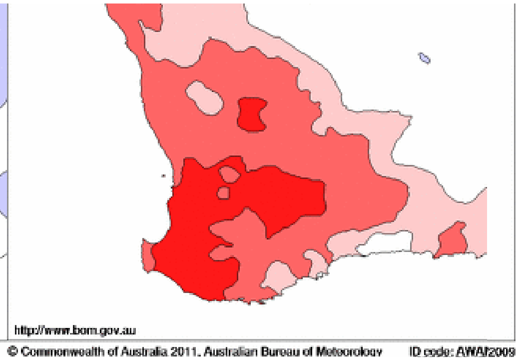




Nov 2007 – Oct 2008 Deciles



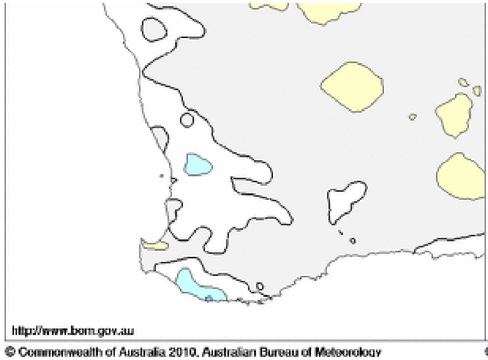
Nov 2008 – Oct 2009 Deciles



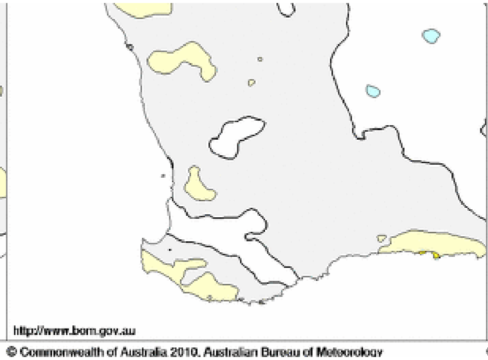
Nov 2009 – Oct 2010 Deciles

Appendix 76.

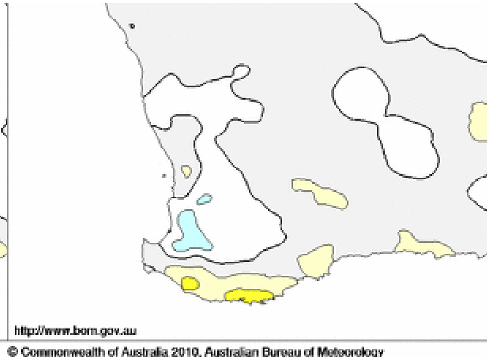
'12 months prior to Nov' rainfalls: 2001-2010.



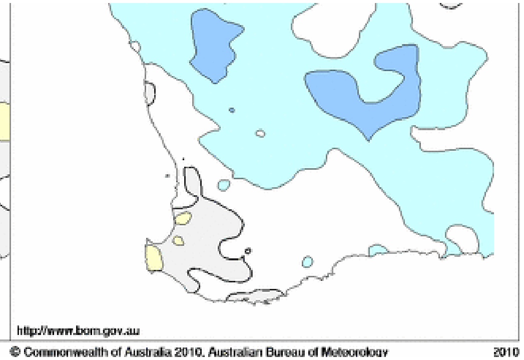
Sep 1980 – Aug 1981 Anomalies (mm)



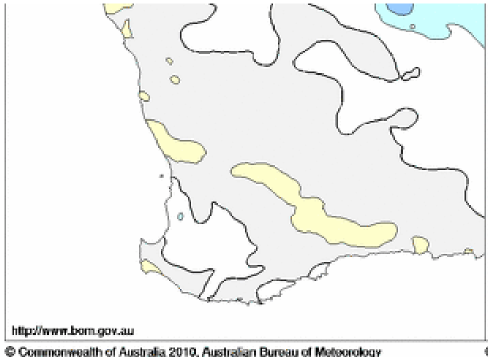
Sep 1981 – Aug 1982 Anomalies (mm)



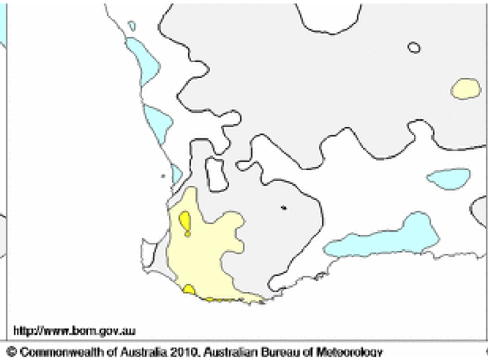
Sep 1982 – Aug 1983 Anomalies (mm)



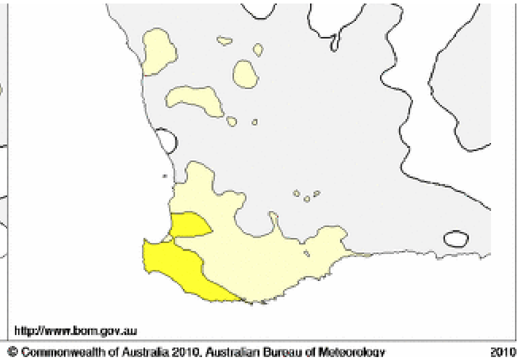
Sep 1983 – Aug 1984 Anomalies (mm)



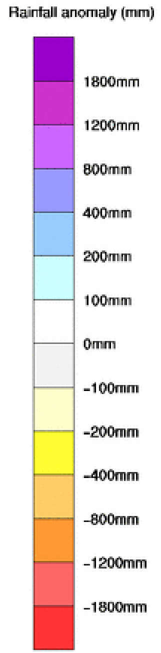
Sep 1984 – Aug 1985 Anomalies (mm)

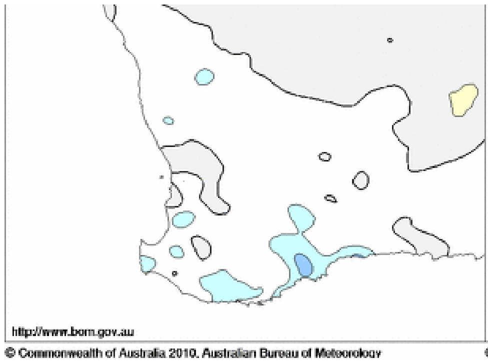


Sep 1985 – Aug 1986 Anomalies (mm)

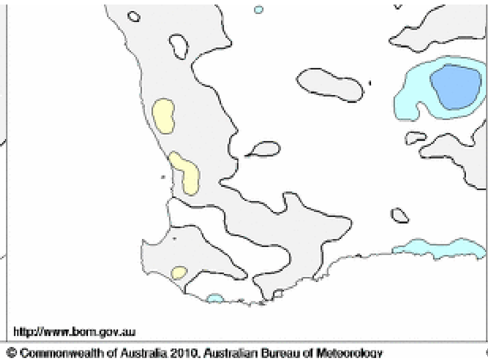


Sep 1986 – Aug 1987 Anomalies (mm)

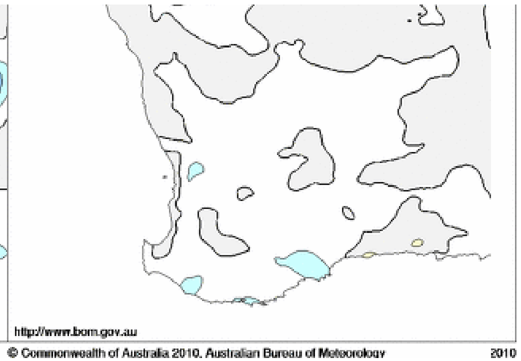




Sep 1987 – Aug 1988 Anomalies (mm)



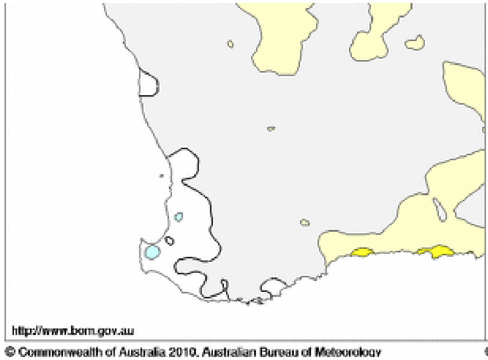
Sep 1988 – Aug 1989 Anomalies (mm)



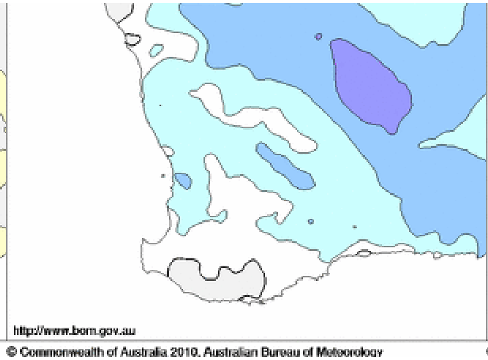
Sep 1989 – Aug 1990 Anomalies (mm)

Appendix 77.

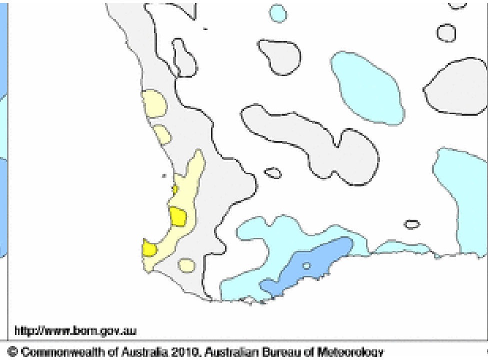
'12 months prior to Sep' rainfall anomalies: 1981-1990.



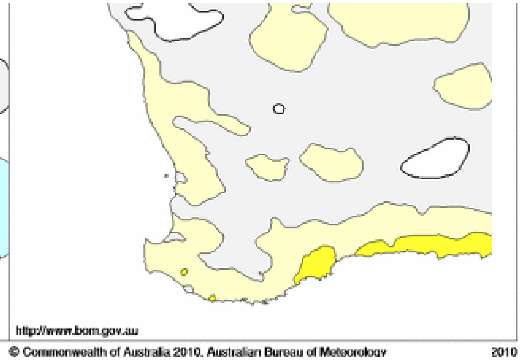
Sep 1990 – Aug 1991 Anomalies (mm)



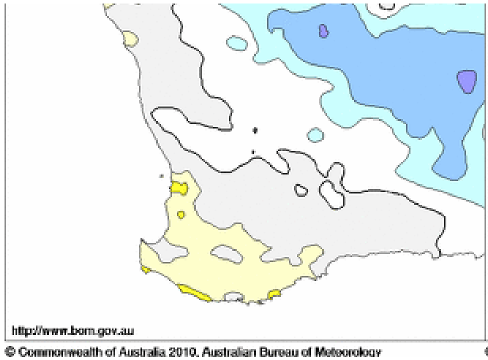
Sep 1991 – Aug 1992 Anomalies (mm)



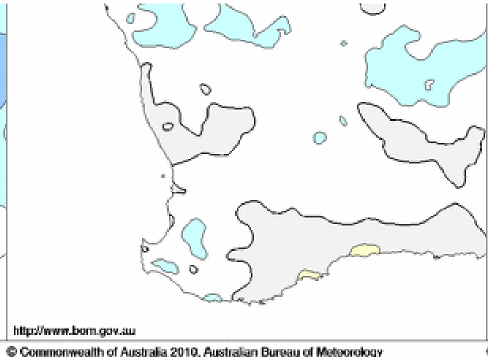
Sep 1992 – Aug 1993 Anomalies (mm)



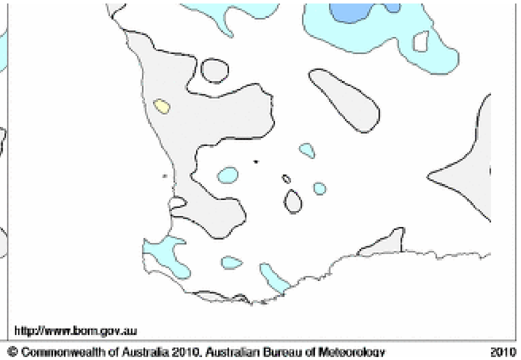
Sep 1993 – Aug 1994 Anomalies (mm)



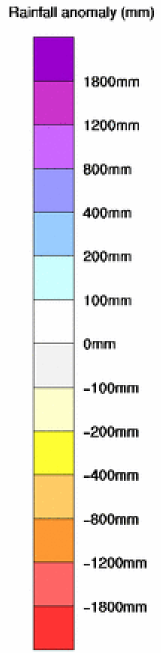
Sep 1994 – Aug 1995 Anomalies (mm)

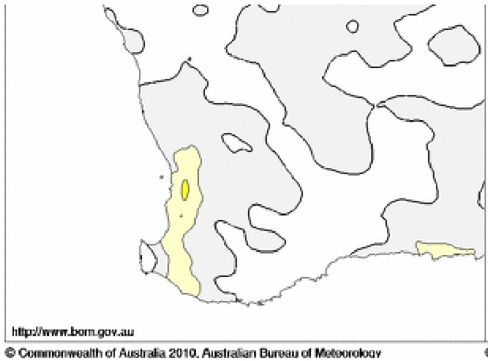


Sep 1995 – Aug 1996 Anomalies (mm)

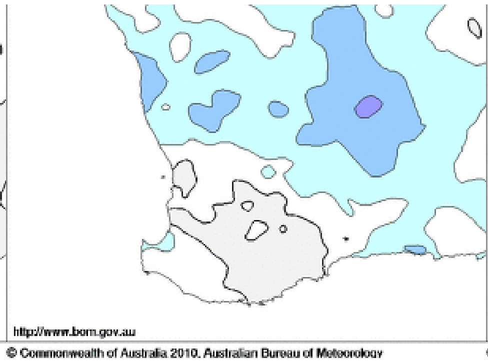


Sep 1996 – Aug 1997 Anomalies (mm)

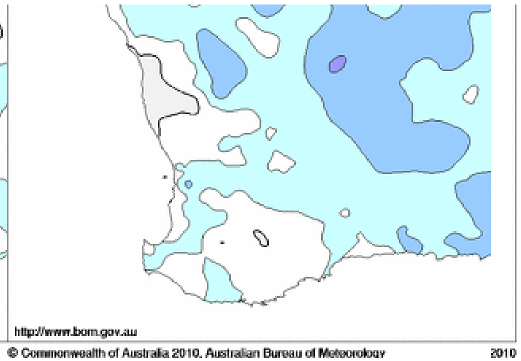




Sep 1997 – Aug 1998 Anomalies (mm)



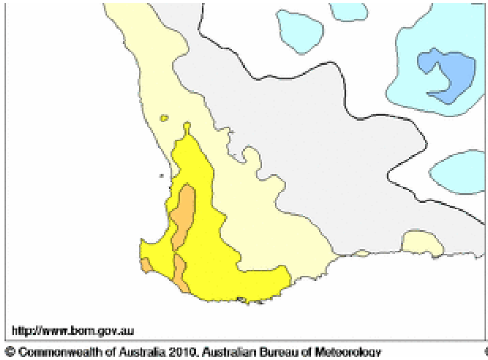
Sep 1998 – Aug 1999 Anomalies (mm)



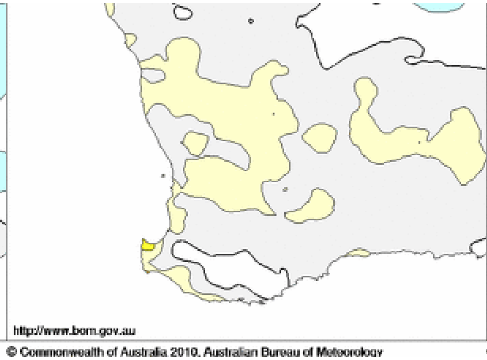
Sep 1999 – Aug 2000 Anomalies (mm)

Appendix 78.

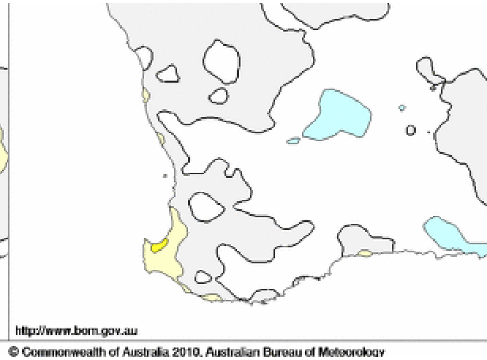
‘12 months prior to Sep’ rainfall anomalies: 1991-2000.



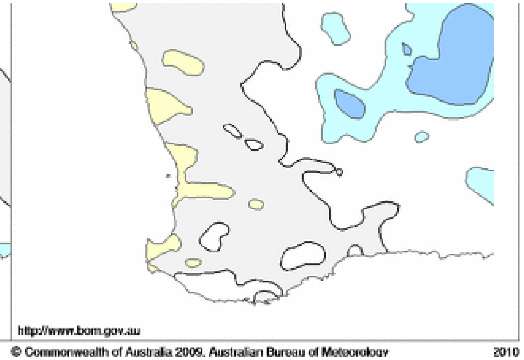
Sep 2000 – Aug 2001 Anomalies (mm)



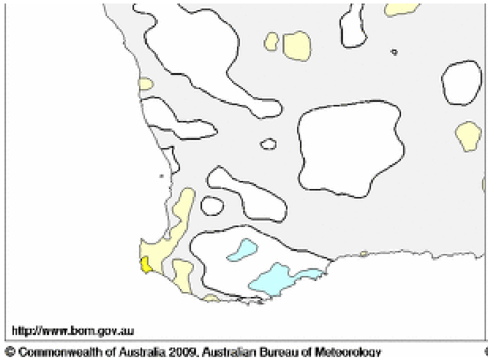
Sep 2001 – Aug 2002 Anomalies (mm)



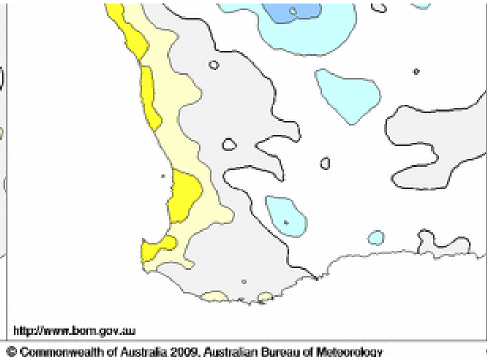
Sep 2002 – Aug 2003 Anomalies (mm)



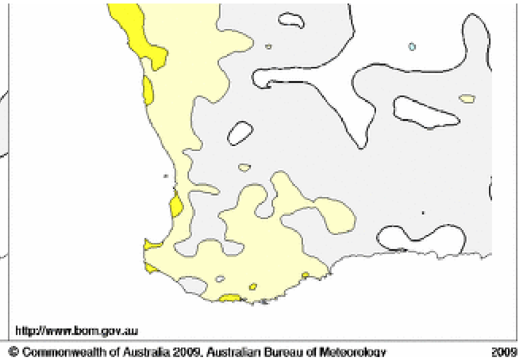
Sep 2003 – Aug 2004 Anomalies (mm)



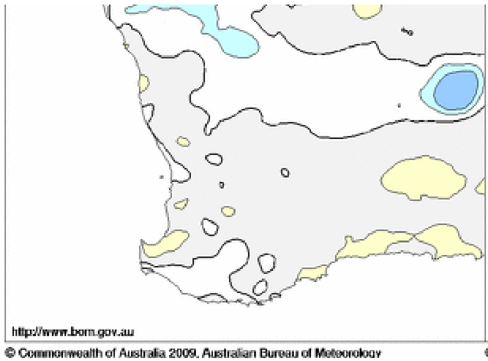
Sep 2004 – Aug 2005 Anomalies (mm)



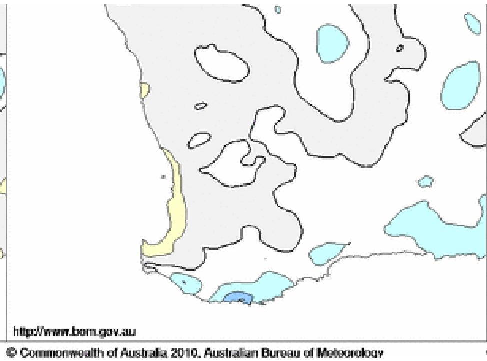
Sep 2005 – Aug 2006 Anomalies (mm)



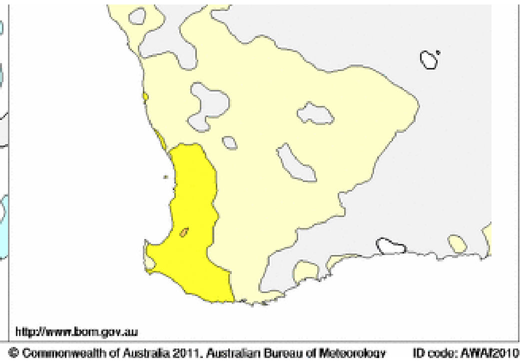
Sep 2006 – Aug 2007 Anomalies (mm)



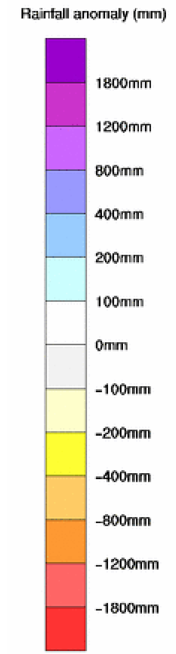
Sep 2007 – Aug 2008 Anomalies (mm)



Sep 2008 – Aug 2009 Anomalies (mm)

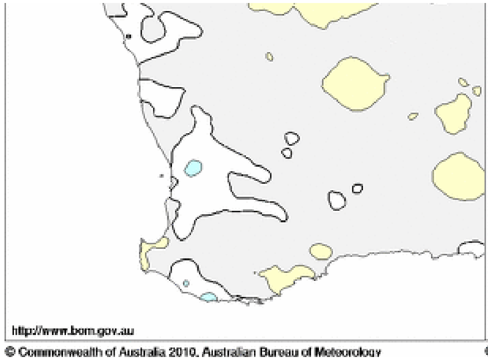


Sep 2009 – Aug 2010 Anomalies (mm)

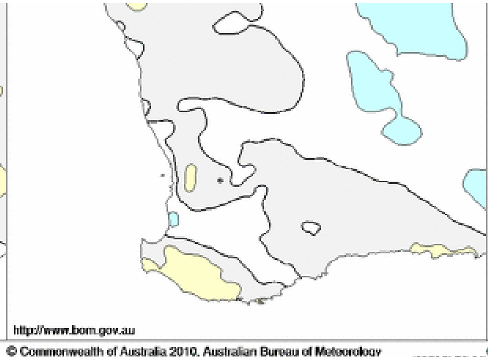


Appendix 79.

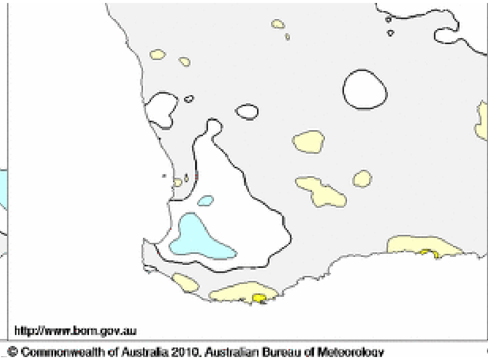
'12 months prior to Sep' rainfall anomalies: 2001-2010.



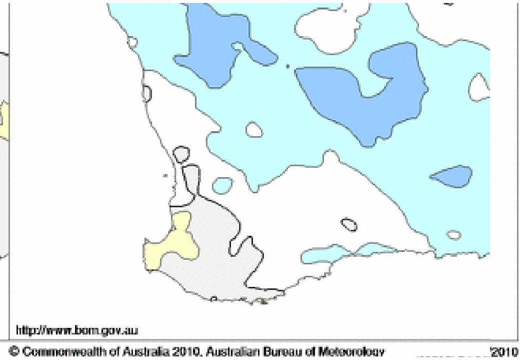
Nov 1980 – Oct 1981 Anomalies (mm)



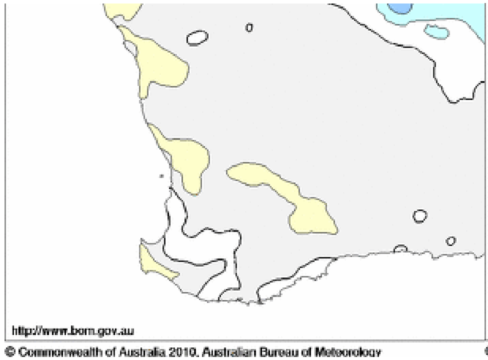
Nov 1981 – Oct 1982 Anomalies (mm)



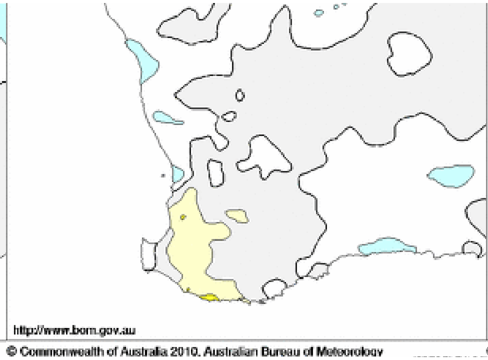
Nov 1982 – Oct 1983 Anomalies (mm)



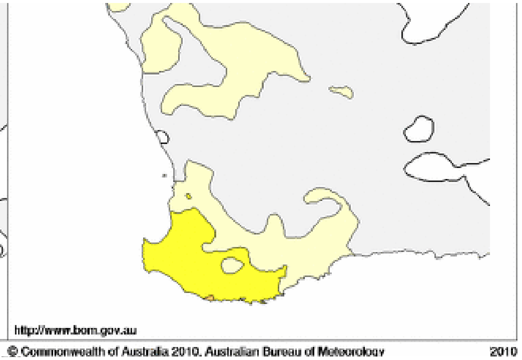
Nov 1983 – Oct 1984 Anomalies (mm)



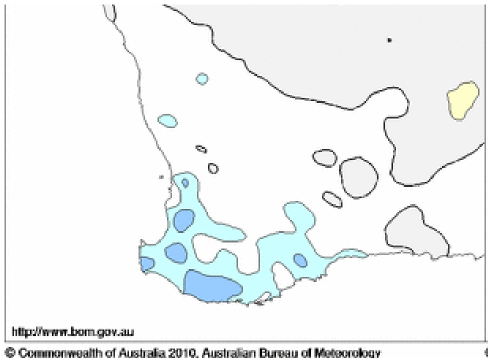
Nov 1984 – Oct 1985 Anomalies (mm)



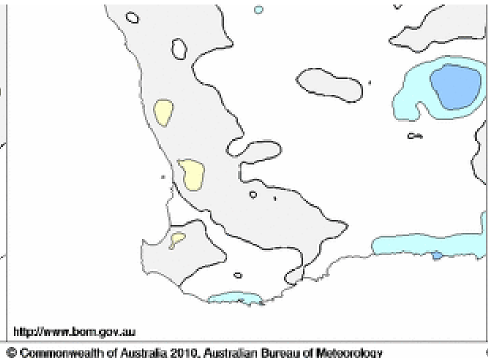
Nov 1985 – Oct 1986 Anomalies (mm)



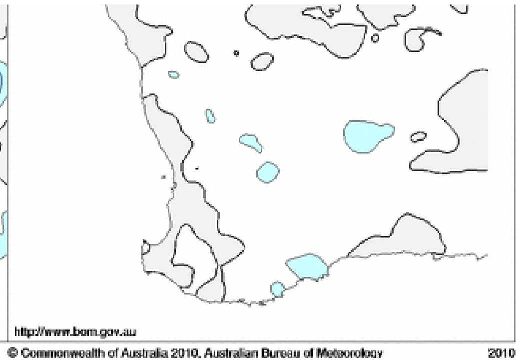
Nov 1986 – Oct 1987 Anomalies (mm)



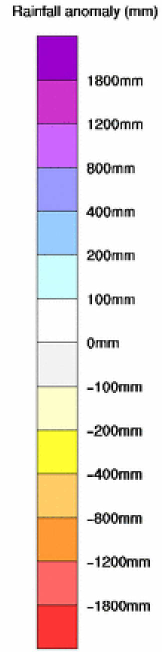
Nov 1987 – Oct 1988 Anomalies (mm)



Nov 1988 – Oct 1989 Anomalies (mm)

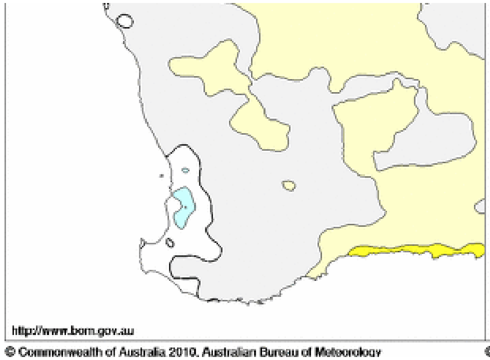


Nov 1989 – Oct 1990 Anomalies (mm)

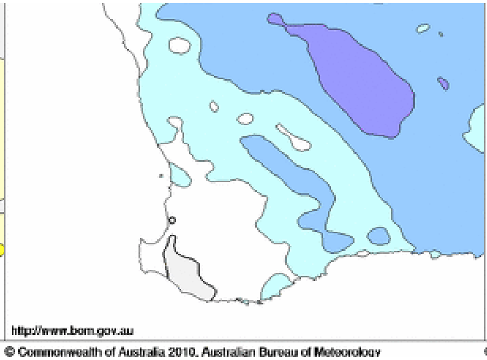


Appendix 80.

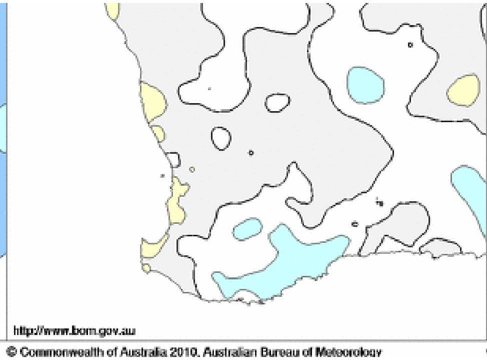
‘12 months prior to Nov’ rainfall anomalies: 1981-1990.



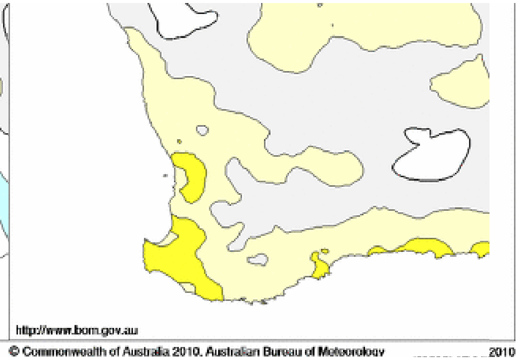
Nov 1990 – Oct 1991 Anomalies (mm)



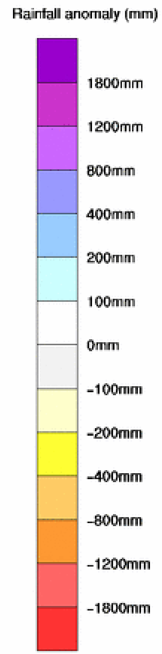
Nov 1991 – Oct 1992 Anomalies (mm)

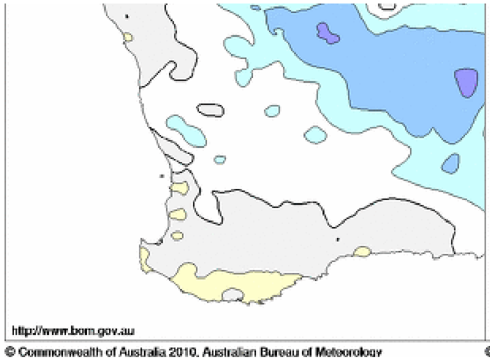


Nov 1992 – Oct 1993 Anomalies (mm)

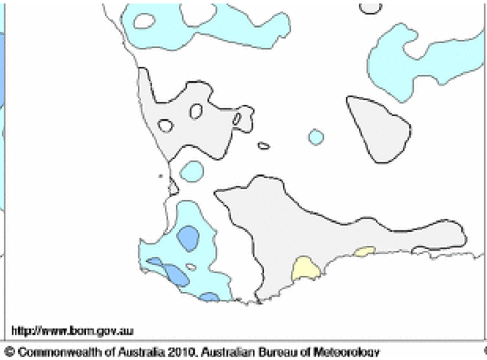


Nov 1993 – Oct 1994 Anomalies (mm)

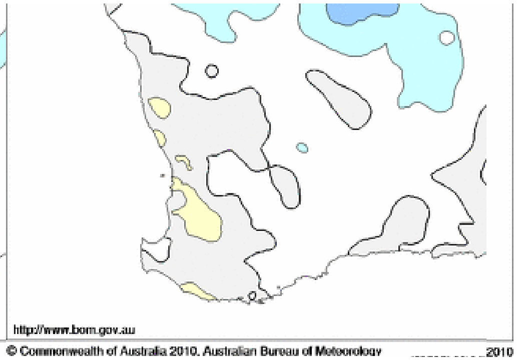




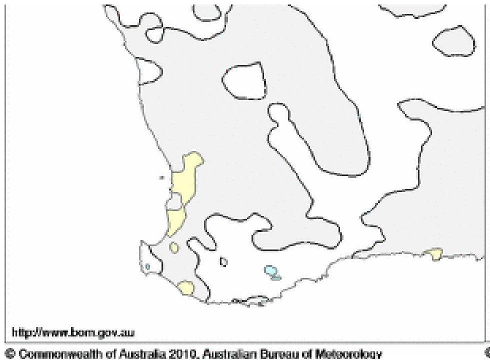
Nov 1994 – Oct 1995 Anomalies (mm)



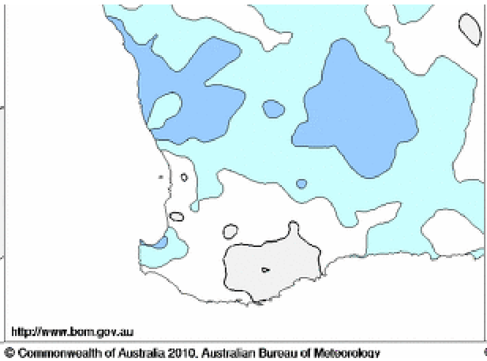
Nov 1995 – Oct 1996 Anomalies (mm)



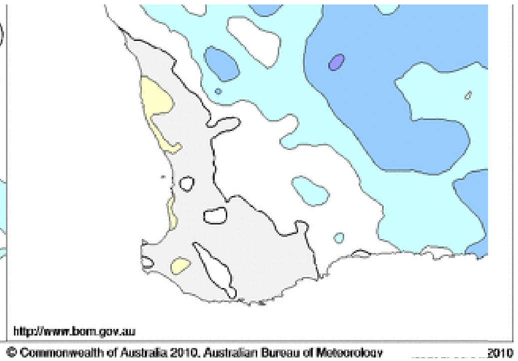
Nov 1996 – Oct 1997 Anomalies (mm)



Nov 1997 – Oct 1998 Anomalies (mm)



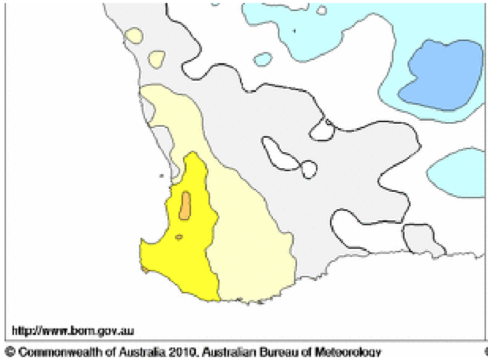
Nov 1998 – Oct 1999 Anomalies (mm)



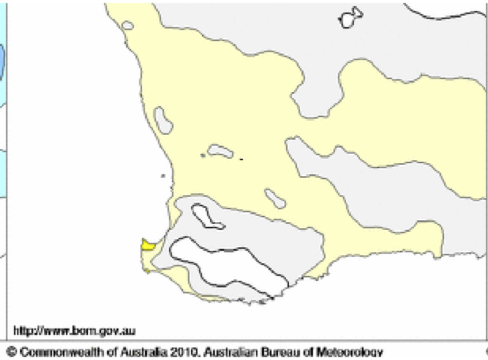
Nov 1999 – Oct 2000 Anomalies (mm)

Appendix 81.

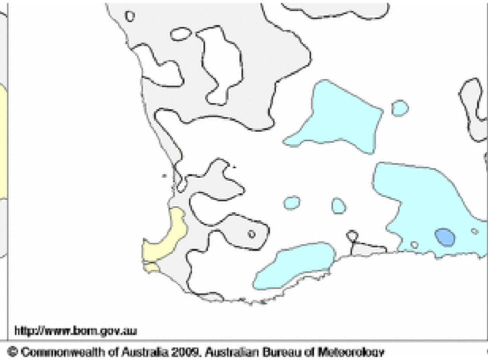
'12 months prior to Nov' rainfall anomalies: 1991-2000.



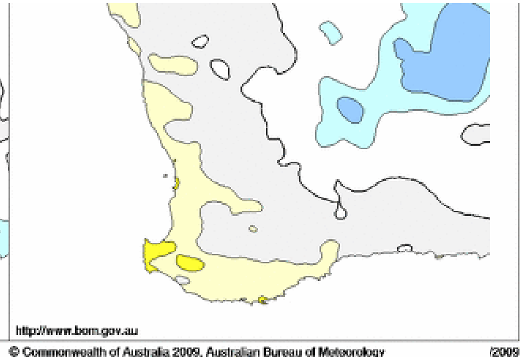
Nov 2000 – Oct 2001 Anomalies (mm)



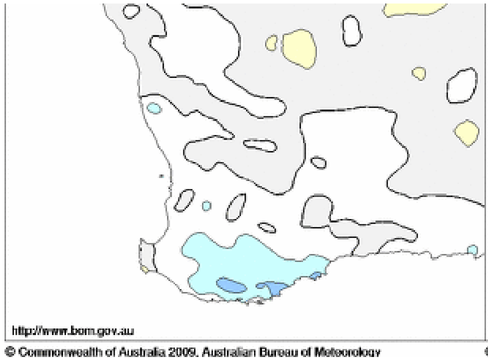
Nov 2001 – Oct 2002 Anomalies (mm)



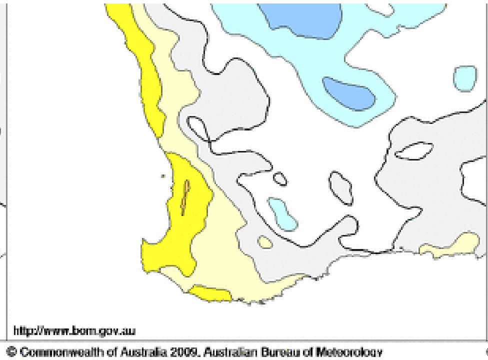
Nov 2002 – Oct 2003 Anomalies (mm)



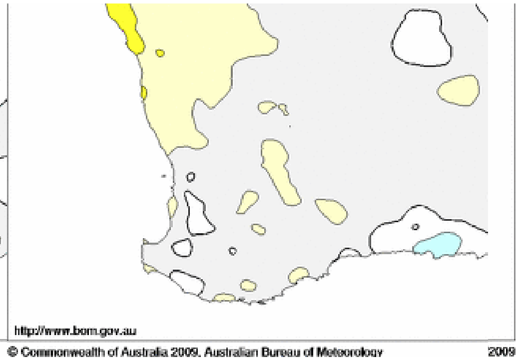
Nov 2003 – Oct 2004 Anomalies (mm)



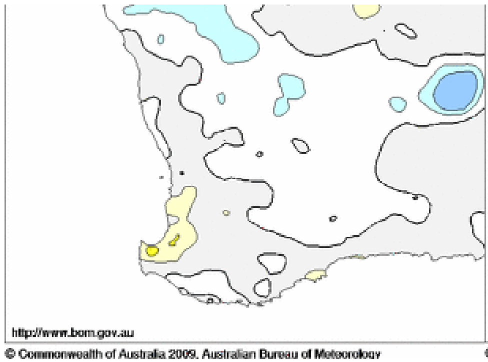
Nov 2004 – Oct 2005 Anomalies (mm)



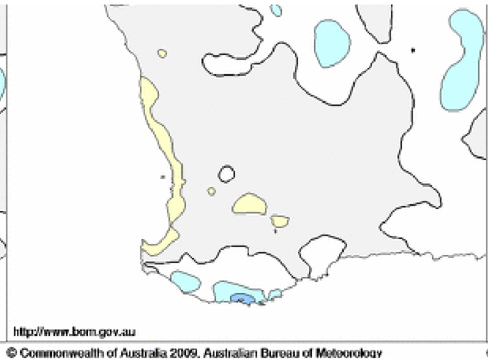
Nov 2005 – Oct 2006 Anomalies (mm)



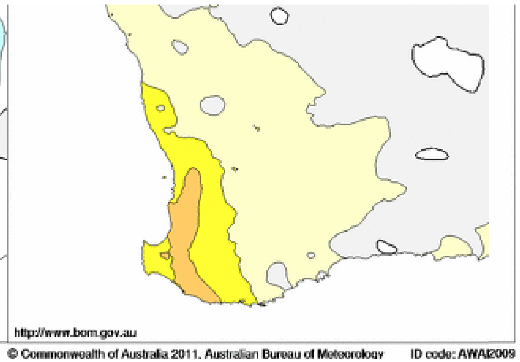
Nov 2006 – Oct 2007 Anomalies (mm)



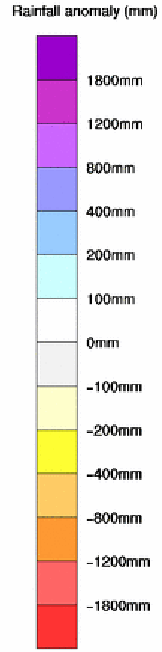
Nov 2007 – Oct 2008 Anomalies (mm)



Nov 2008 – Oct 2009 Anomalies (mm)

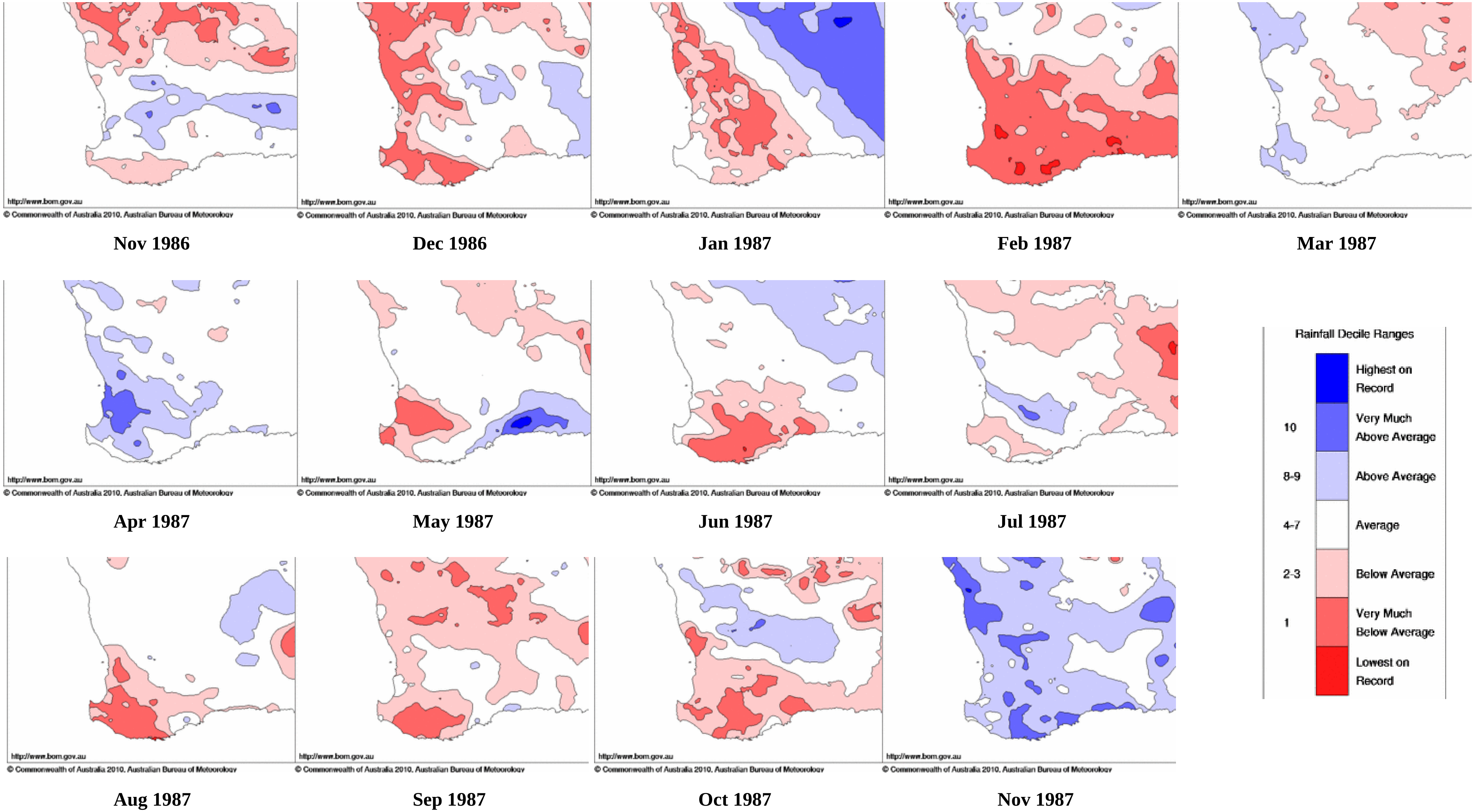


Nov 2009 – Oct 2010 Anomalies (mm)

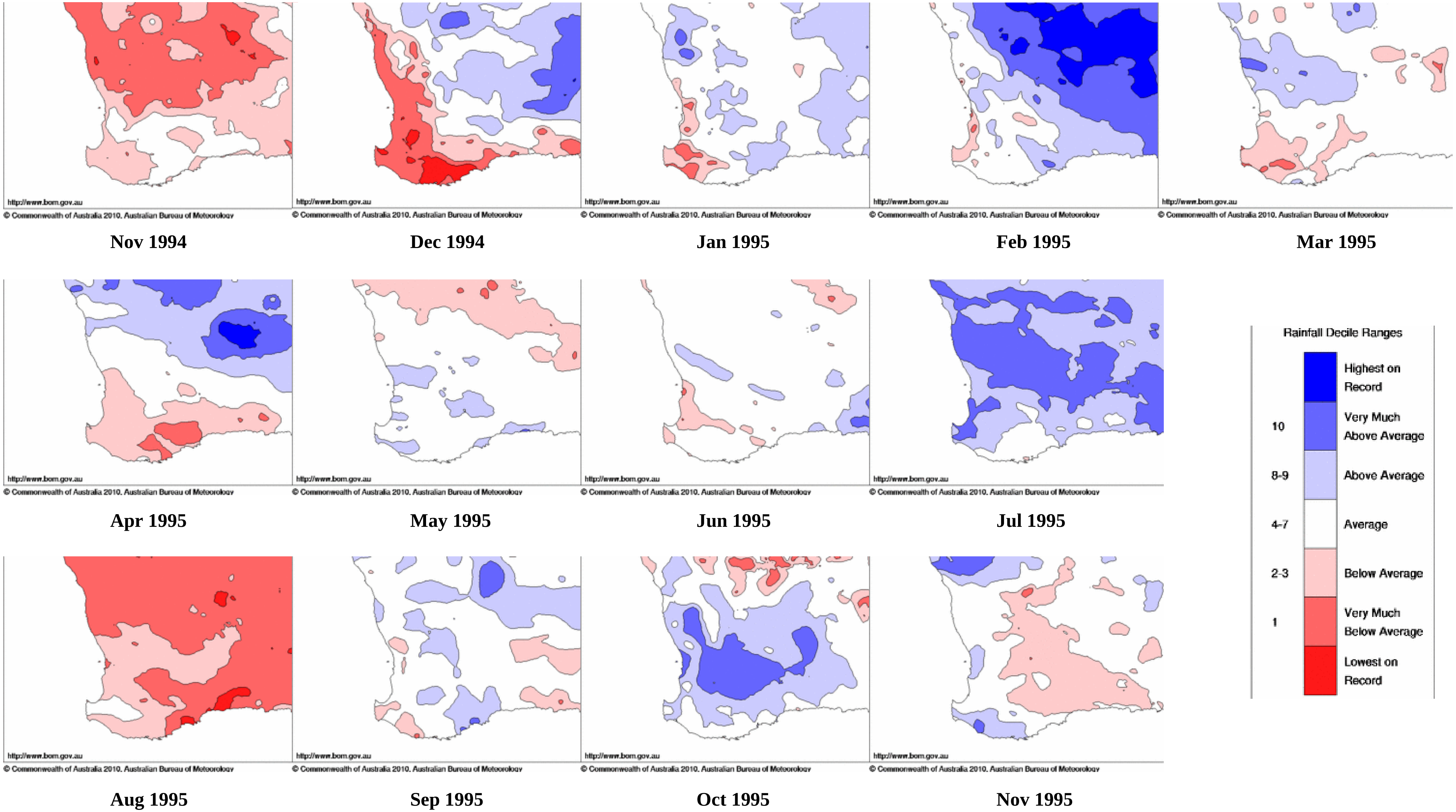


Appendix 82.

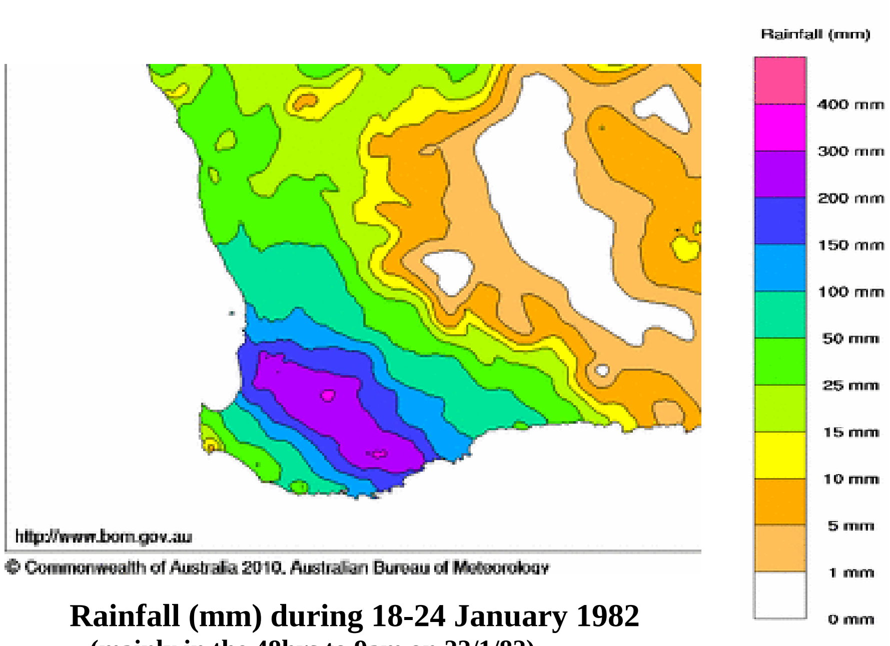
'12 months prior to Nov' rainfall anomalies: 2001-2010.



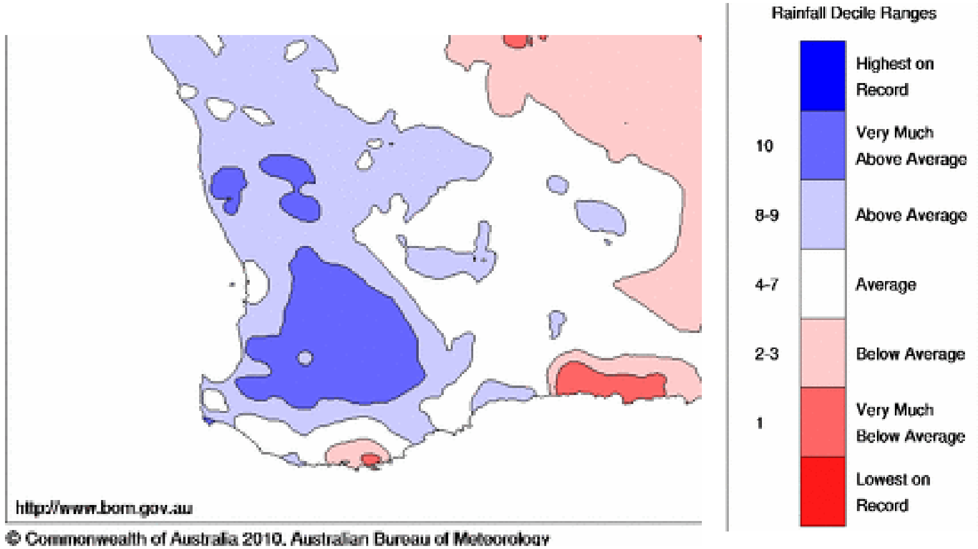
Appendix 83. Nov 1986 – Nov 1987 monthly rainfall deciles.



Appendix 84. Nov 1994 – Nov 1995 monthly rainfall deciles.



Rainfall (mm) during 18-24 January 1982
(mainly in the 48hrs to 9am on 22/1/82)

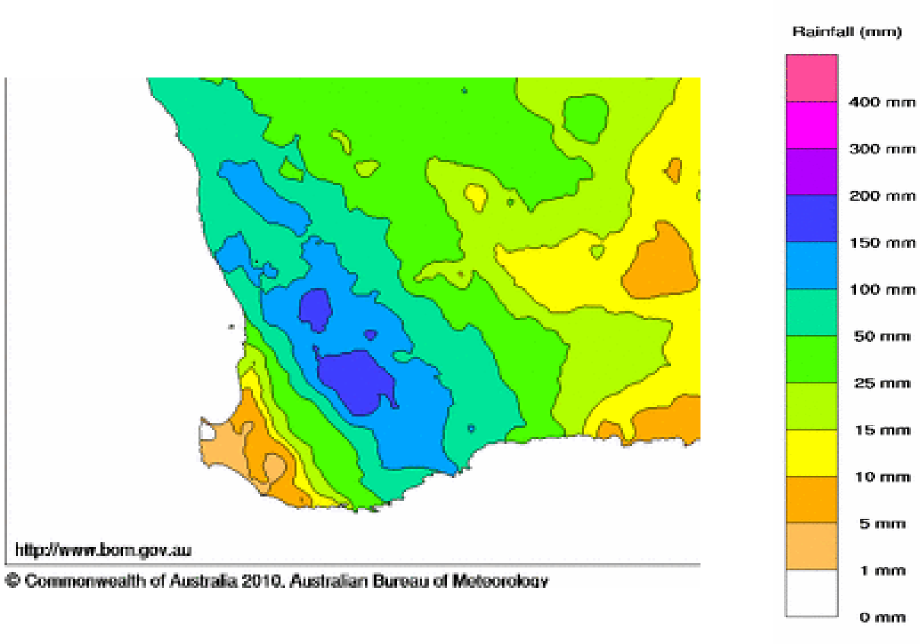


Rainfall deciles 1983 winter (Jun-Aug)
(mainly in June 1983)

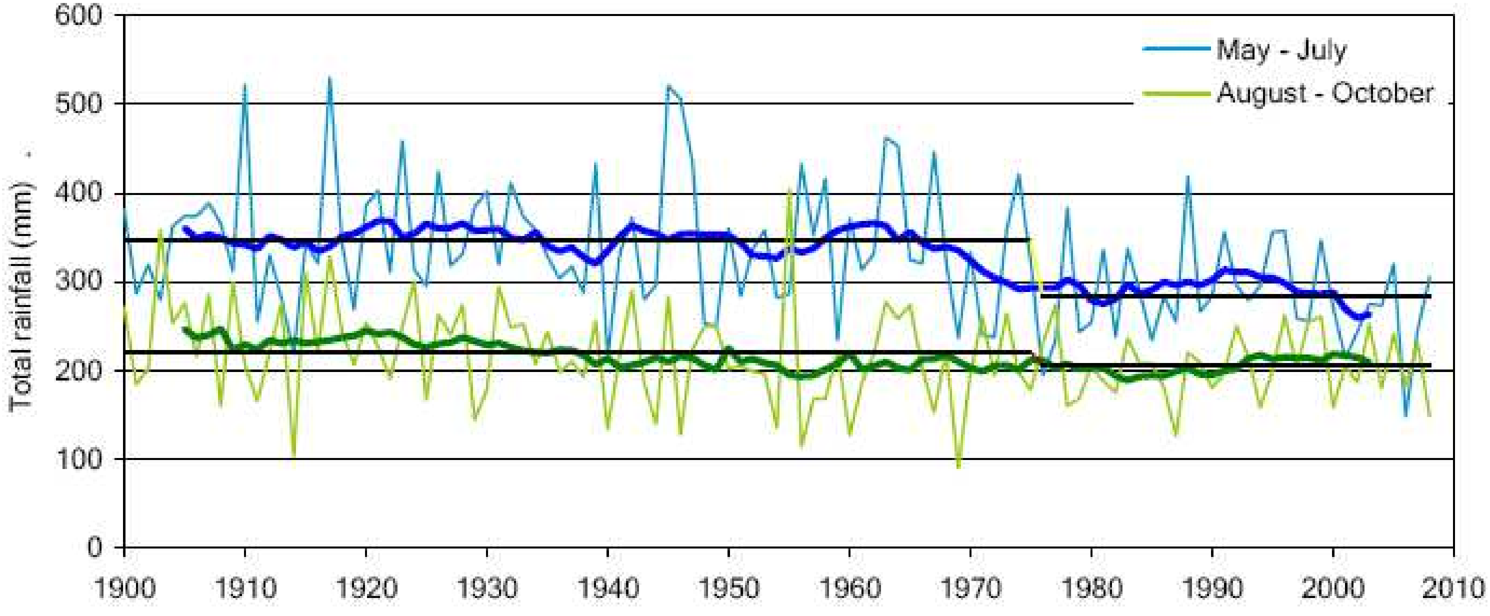
Lake Dumbleyung half-filled in January 1982 and over-flowed following the 1983 winter. Other wetlands in the area of highest Jan 1982 and winter 1983 rainfalls were similarly affected (e.g. Coyrecup, Coomelberrup, Parkeyerring, Martinup, Towerrinning, Little White, Toolibin).

The January 1982 rainfall was from ex-Tropical Cyclone 'Bruno'.

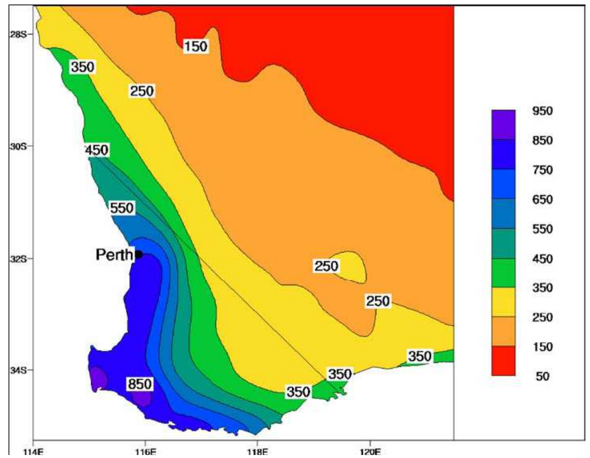
Appendix 85. Rainfall (mm) in January 1982 and Rainfall Deciles in winter 1983.



Appendix 86. Rainfall (mm) during 25-31 January 1990 **(mainly in 24hrs to 9am on 29/1/90)**

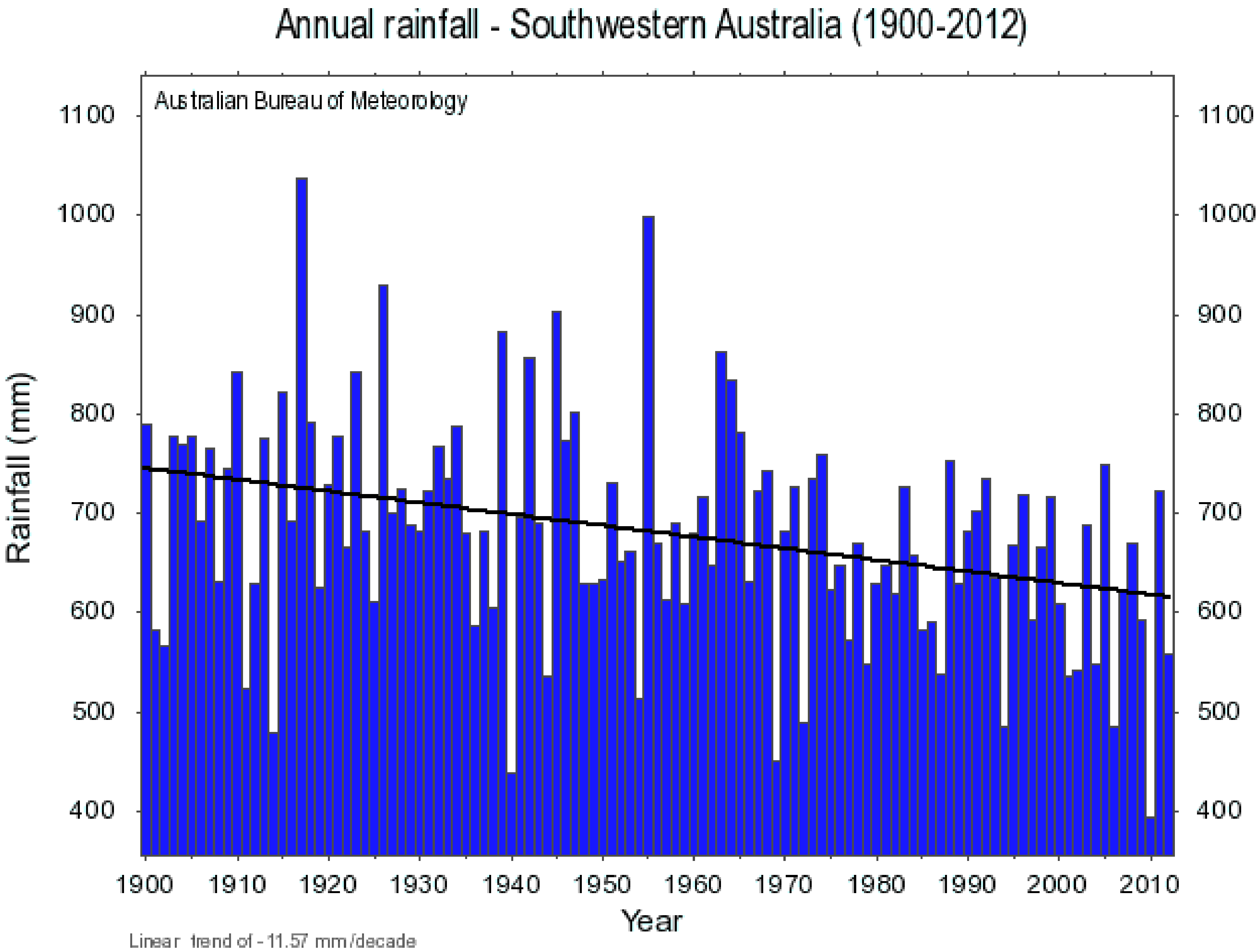


'Time series of rainfall in south-west Western Australia. Means for the periods 1900-1974 and 1975 to 2008 are represented by horizontal lines. The thicker solid lines are 11-year moving averages (Bureau of Meteorology data for the IOCI region south-west of a line joining 30S, 115E and 35S, 120E, Bates *et al.*, 2008a)'

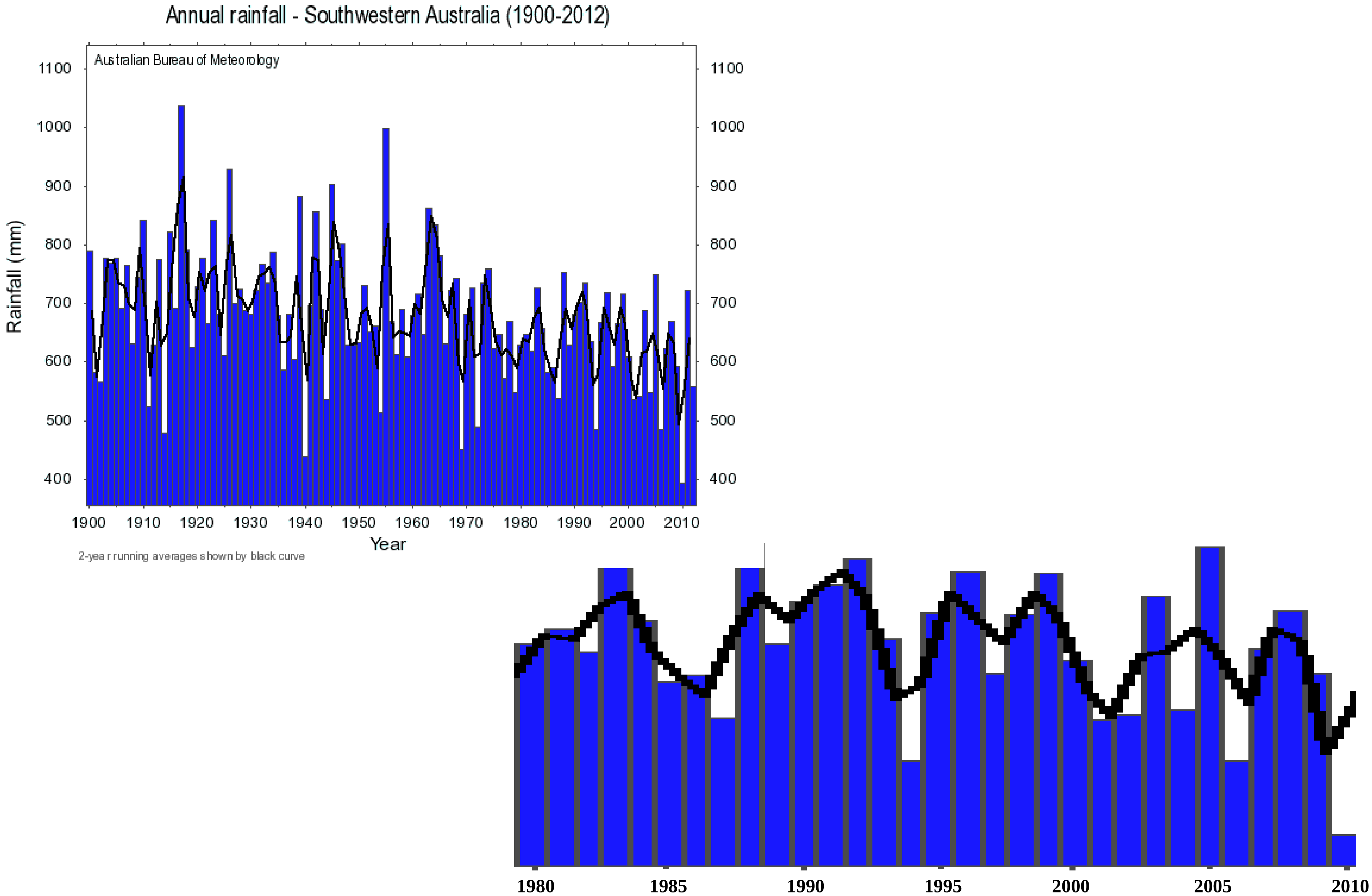


'Mean May to October rainfall (mm) for the period 1901 to 2000. Region southwest of the line connecting the coastline at 30°S to (35°S, 120°E) is used to define spatial rainfall averages for Southwest Western Australia'

Appendix 87. May-Jul & Aug-Oct rainfall in south-western Australia in 1900-1974 and 1975-2008 and map showing the boundary of the south-west IOCI region (From: Charles SP *et al.* (2010) *Climate analyses for south-west Western Australia.* A report to the Australian Government from the CSIRO South-West Western Australia Sustainable Yields Project. CSIRO, Australia. 83 pp.

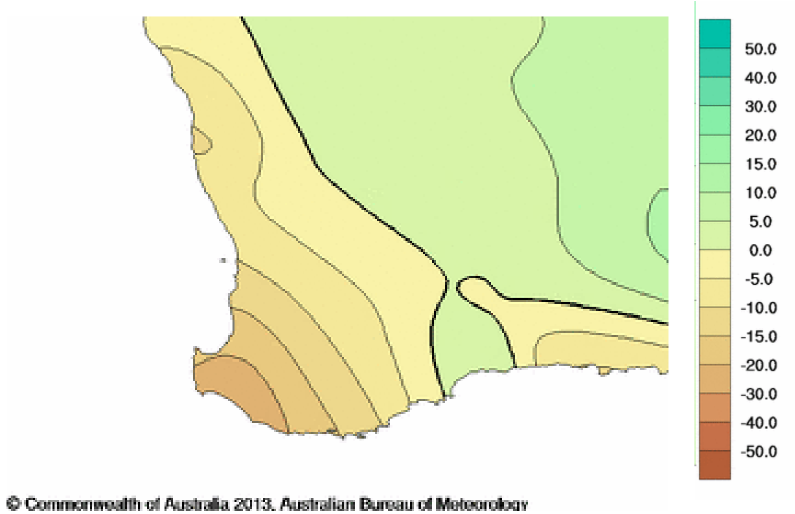


Appendix 88. Annual rainfall – ‘Southwestern Australia’ (1900-2012) with linear trend line decreasing at 11.57 mm/decade.

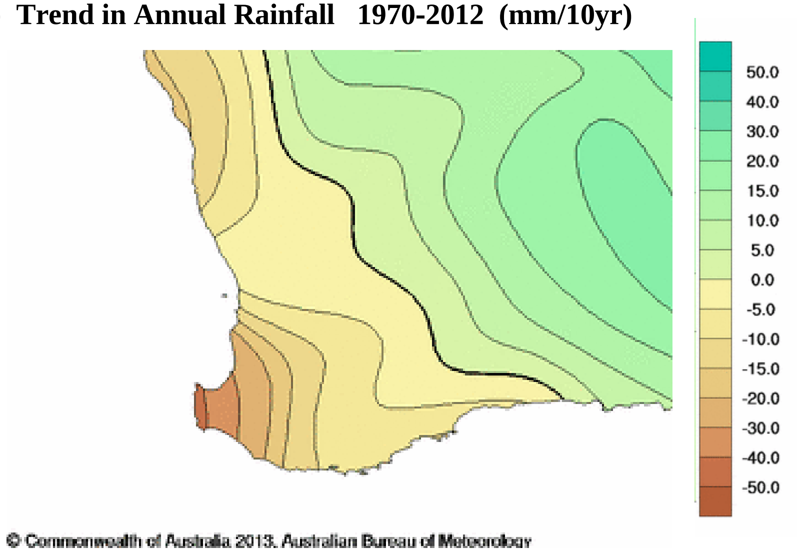


Appendix 89. Annual Rainfall – 'Southwestern Australia' 1900-2012 and (<u>enlargement</u>) <u>1980-2010 with 2-year running average</u>

(a) Trend in Annual Rainfall 1900-2012 (mm/10yr)



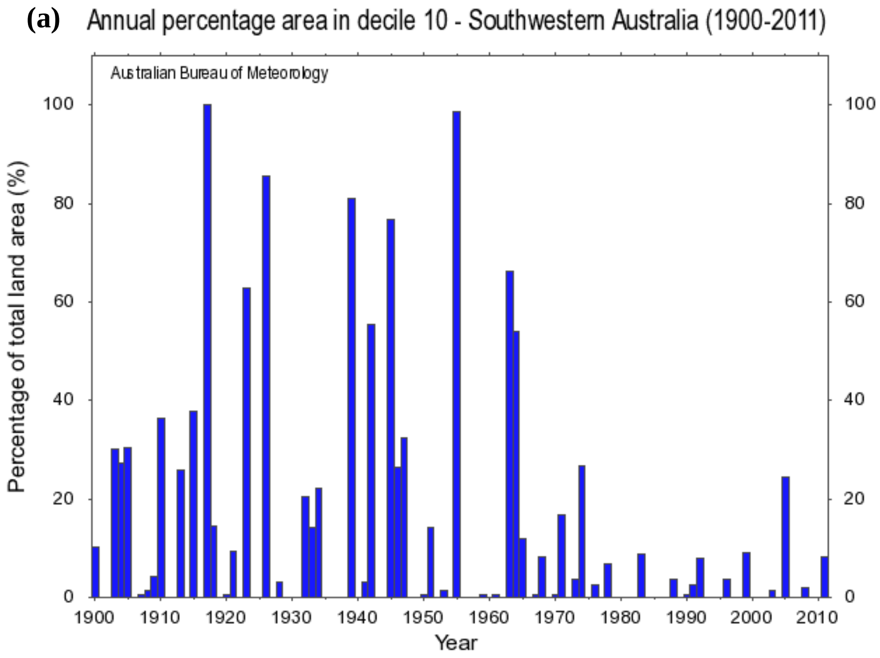
(b) Trend in Annual Rainfall 1970-2012 (mm/10yr)



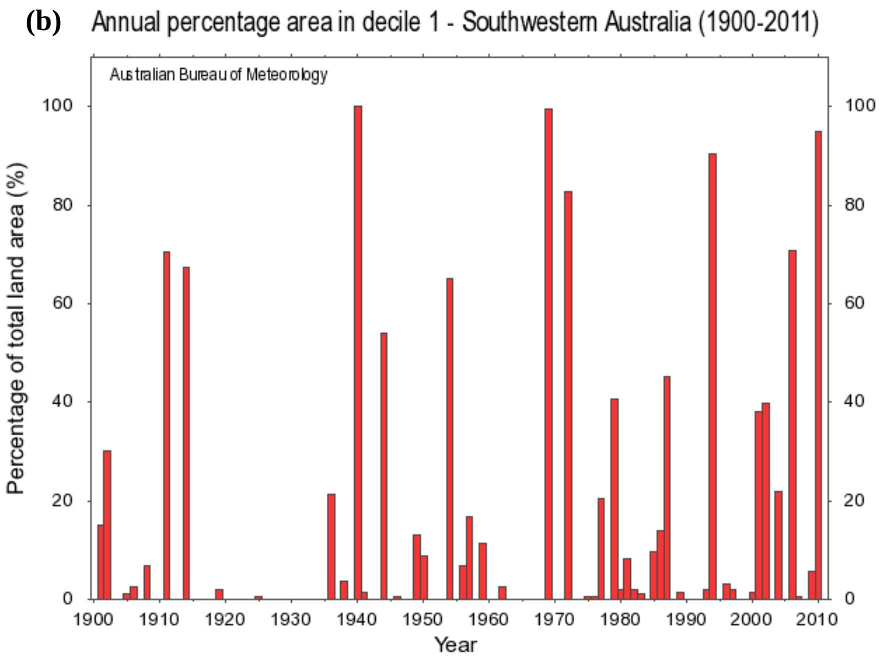
Appendix 90.

Trends in annual rainfall in south-western Australia since (a) 1900 & (b) 1970.

(a)



(b)

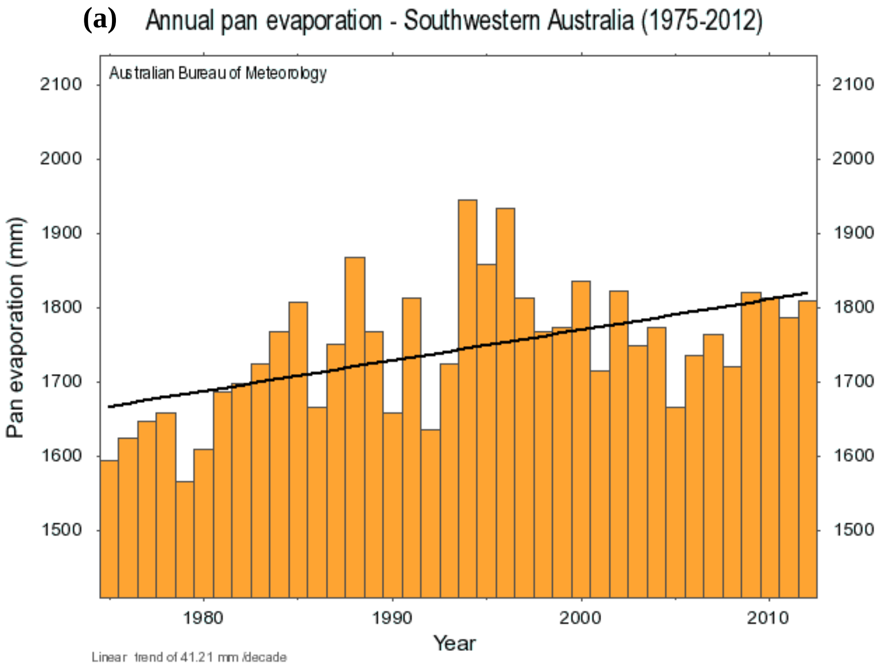


Appendix 91.

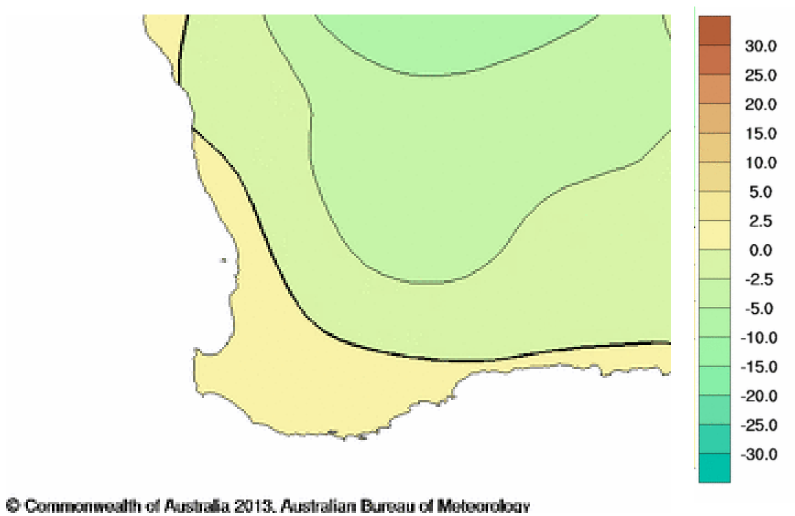
(a) Annual percentage of SW land area in rainfall decile 10 (<u>wettest</u> 10% of rainfall records).

(b) Annual percentage of SW land area in rainfall decile 1 (<u>driest</u> 10% of rainfall records)

(a)



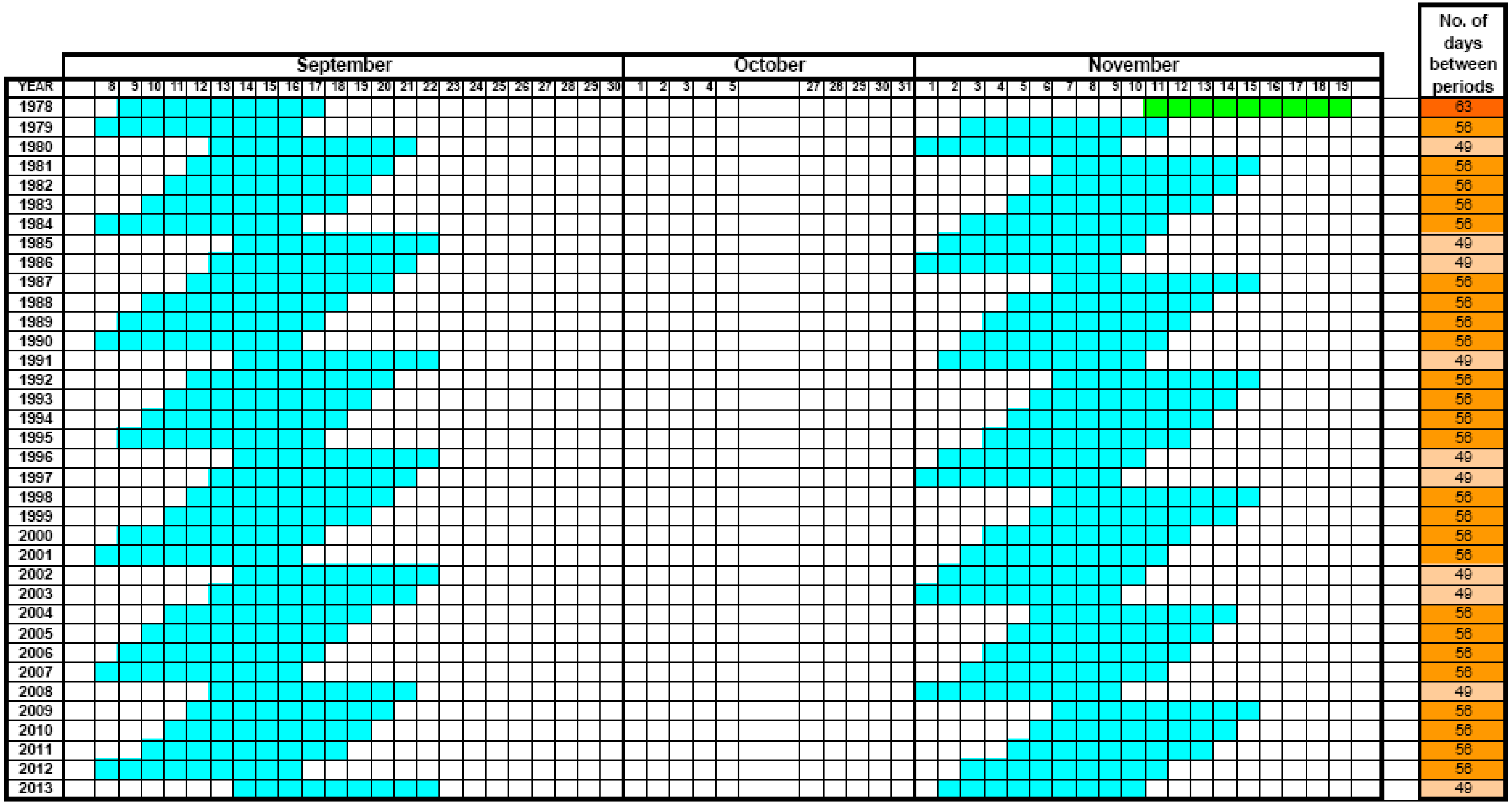
(b) Change in annual pan evaporation (1970-2012)



Appendix 92.

(a) Annual pan evaporation in SW (1975-2012) with linear trend line increasing at 41.2 mm/decade

(b) Change in annual pan evaporation (1970-2012) in mm/year.



<u>Notes:</u>

1. While SWWMP monitoring began (at only four wetlands) in 1977, routine September and November monitoring periods were not adopted until 1978.
2. The routine September monitoring period is the nine day period commencing on the *second* Saturday of the month.
2. The routine November monitoring period is the nine day period commencing on the *first* Saturday of the month.
3. *In 1978 only*, the routine November monitoring period began on the *second* Saturday of the month (*not* on the first Saturday as in all subsequent Novembers).
4. 'No. of days between periods' is number of days from start of routine September monitoring period until start of routine November monitoring period each year.
5. The day (1-9) of monitoring of *individual wetlands* was variable within monitoring periods. For example, a wetland could have been monitored on the first day of a monitoring period on one occasion and the last day of the monitoring period on another.

Appendix 93. Routine September and November monitoring periods, 1978-2013.

MET. DIST.	LAKE No.	LAKE NAME	DEPTH (METRES) NOV 1978	NOV 1979	NOV 1980	SALINITY (PPT) NOV 1978	NOV 1979	NOV 1980
NORTH COASTAL	1	LOGUE		DRY	DRY			
	2	EGANU	2.18	0.60	DRY	10	104	
	3	PINJARREGA		1.10	DRY		112	
	4	STREETS	0.04	DRY	DRY	14		
	5	HINDS		DRY	DRY			
	6	NINAN	0.25	0.23	DRY		340	
NORTH CENTRAL	7	WALYOURMOURING	0.03	0.03	DRY	85	204	
	8	DOWERIN		DRY	DRY			
	9	CAMPION		DRY	DRY			
	10	NOONYING		0.85	DRY	4.9		
SOUTH CENTRAL	11	BEVERLEY	1.65	0.63	0.24	57	215	121
	12	MEARS	1.74	0.72	DRY	6.6	28	
	13	NONALLING		DRY	0.88			14
	14	BROWN		<0.16	DRY		111	
	15	YEALERING	1.67	0.56	0.32	15	77	98
	16	KONDININ		0.20	DRY		317	
	17	DULBINNING		DRY	DRY			
	18	TOOLIBIN	DRY	DRY	DRY			
	19	WALBYRING		DRY	DRY			
	20	TAARBLIN	DRY	DRY	DRY			
	21	BOKAN		DRY	0.02			198
	22	LITTLE WHITE		DRY	0.47			
	23	BRYDE		DRY	DRY			
	24	KWOBRUP		0.14	DRY		27	
	25	COYRECUP	1.00	DRY	<0.13	7.2		
	26	CASUARINA	DRY	DRY	<0.49			139
	27	COOMELBERRUP	0.53	DRY	DRY	24		
	28	COBLININE		0.91	1.27		80	65
	29	DUMBLEYUNG		<0.13	0.13		236	351
	30	GUNDARING	0.82	0.48	0.67	108	218	127
	31	PARKEYERRING	0.49	DRY	<0.10	35		181
	32	FLAGSTAFF		DRY	0.14			140
	33	WARDERING	0.82	0.24	0.66	17	72	23
	34	QUEERERUP	0.34	DRY	0.30	166		125
	35	MARTINUP		DRY	0.24			44
	36	TOWERINNING	1.69	0.81	0.54	14	33	46
CENTRAL COASTAL	37	KARAKIN		0.55	0.82		1.2	0.7
	38	WANNAMAL	1.14	1.15	1.24	6.7	10	9
	39	YURINE		1.01	0.66		1.2	1.9
	40	GINGIN 31241		2.08	2.14		1.1	0.7
	41	BAMBUN		2.27	2.31		1.2	1.4
	42	NAMBUNG		DRY	0.07			25
	43	MUNGALA		0.10	0.12		14	11
	44	CHANDALA		0.74	0.82		1.2	1.8
	45	CHITTERING	1.39	1.38	1.45	4.0	3.5	4.0
	46	JANDABUP	1.35	1.25	1.22	0.3	0.3	0.2
	47	JOONDALUP	3.01	2.87	2.88	0.9	0.9	0.8
	48	THOMPSON	0.94	0.17	0.86	2.0	3.7	1.8
	49	FORRESTDALE	0.92	0.30	0.79	2.0	4.5	1.7
SOUTH COASTAL	50	MUIR		0.14	0.17			2.0
	51	BYENUP	2.40	2.27	2.14	2.6	3.3	4.2
	52	TORDIT-GARRUP	3.15	2.91	2.75	0.6	0.8	1.1
	53	POORGINUP	0.55	0.53	0.55	0.3	0.3	0.1
	54	KWORNICUP		0.41	0.26		18	26
	55	PLANTAGANET 25386		0.73	0.48		100	179
	56	MOATES		4.44	4.51		0.3	0.4
	57	PLEASANT VIEW		2.20	1.52		0.2	0.3
	58	JERDACUTTUP		2.41	c1.4		17	46
	59	GORE		1.72	1.35		24	50
	60	SHARK		2.40	2.25		1.0	1.4
	61	WARDEN		1.53	<0.84		27	86
S.E.	62	DUNDAS 33113		0.34	<0.09			310

TABLE 1 : November Depths and Salinities of Gauged Lakes : 1978-1980. Note that sea-water is approx. 35 ppt. and that the upper limit for fresh-water is generally considered to be 1.0 ppt.

Appendix 94. Extracts from Lane & Munro (1980) *Annual rainfall and wetland review – November 1980.* Unpublished report by Research Officer JAK Lane and Technical Officer DR Munro of WA Department of Fisheries & Wildlife for WA Wildlife Authority Bird Committee meeting on 24 Nov 1980.

1978 — 1980 CHANGES IN LAKE DEPTHS

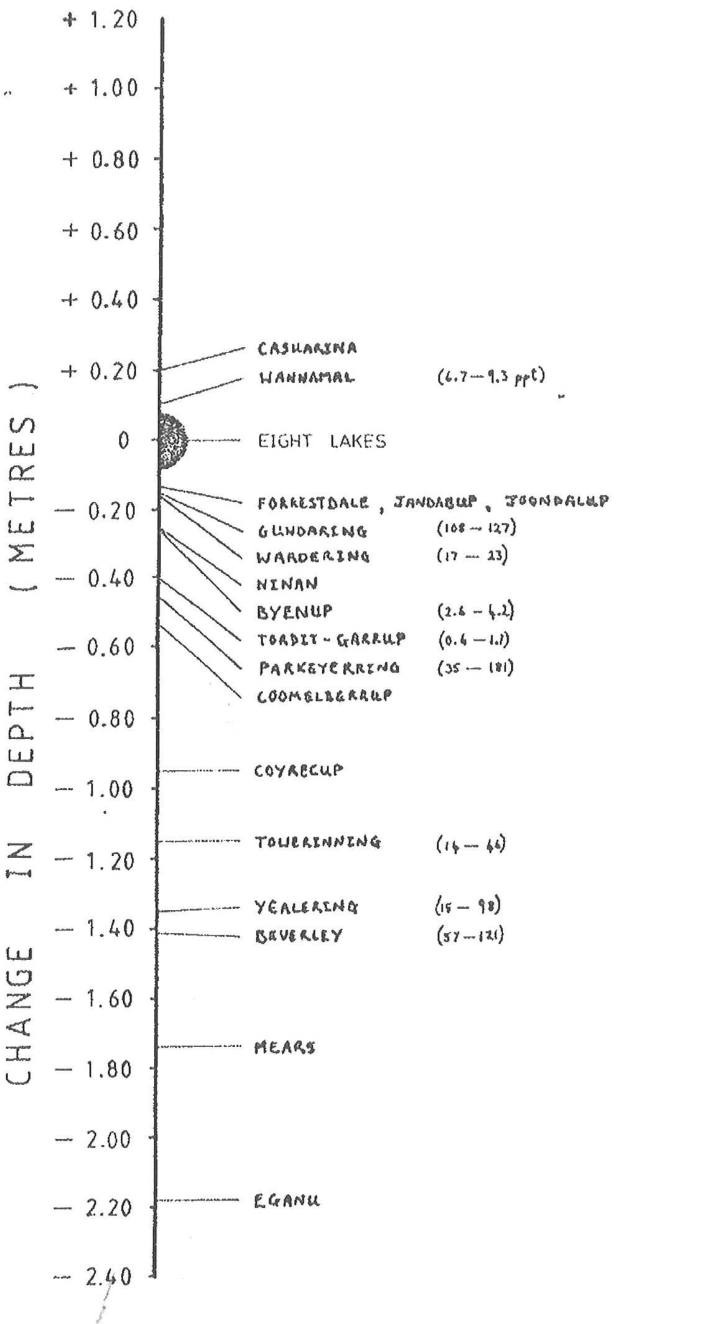


FIGURE 7a. Change in Depth of 26 Gauged Lakes from Nov. 1978 to Nov. 1980. Figures in brackets indicate changes in Salinity (parts per thousand).

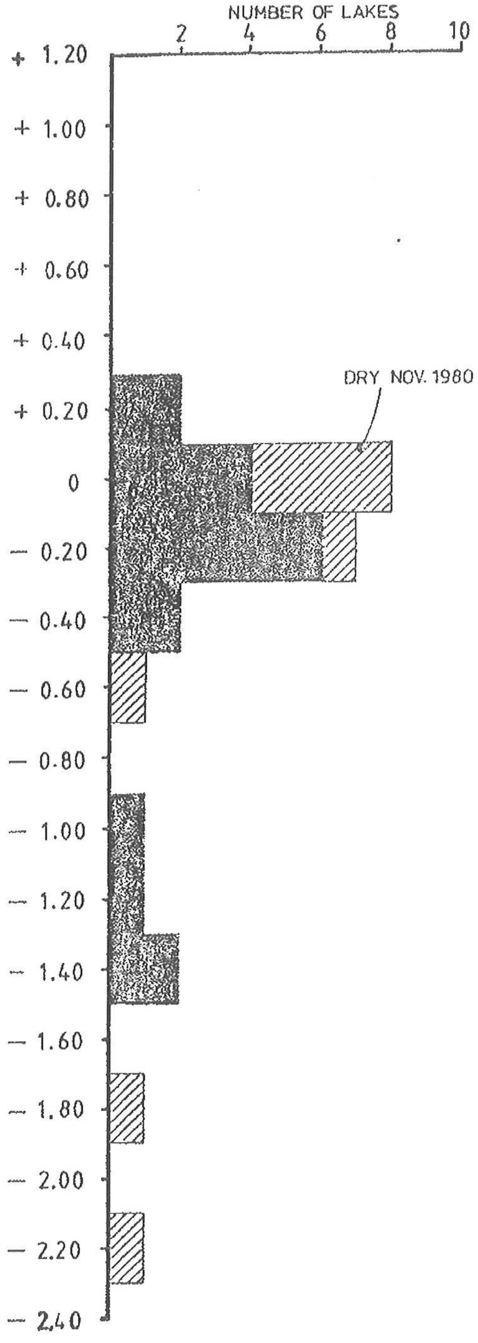


FIGURE 7b. Summary by Histogram.

Appendix 94 continued. Extracts from Lane & Munro (1980).

1979 — 1980 CHANGES IN LAKE DEPTHS

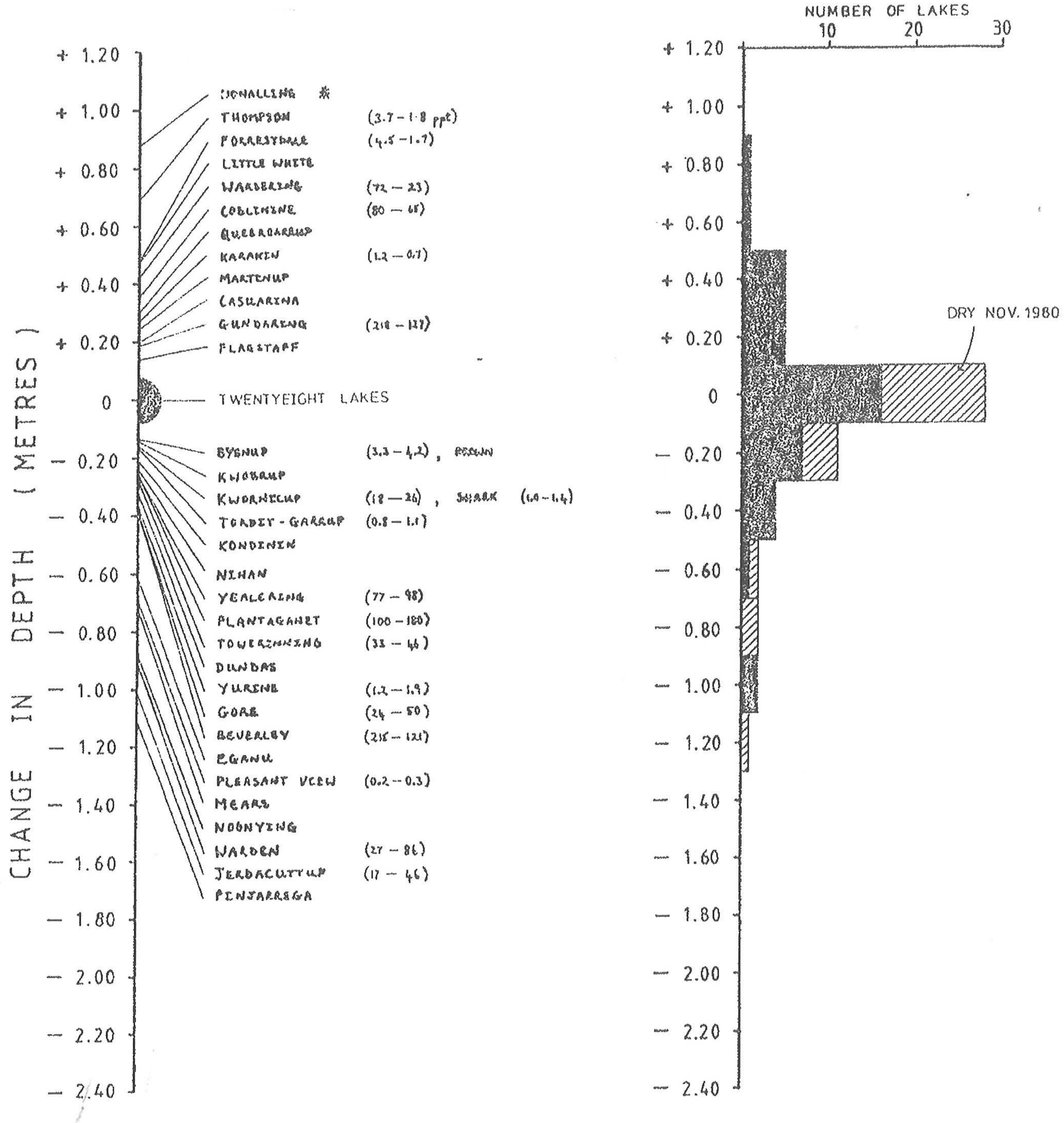


FIGURE 6 a. Change in Depth of 62 Gauged Lakes from Nov. 1979 to Nov. 1980. Figures in brackets indicate changes in Salinity (parts per thousand).

NB. Damming of Lake Nonalling's outlet contributed to this lake's increase in depth.

FIGURE 6 b. Summary by Histogram.

Appendix 94 continued. Extracts from Lane & Munro (1980).

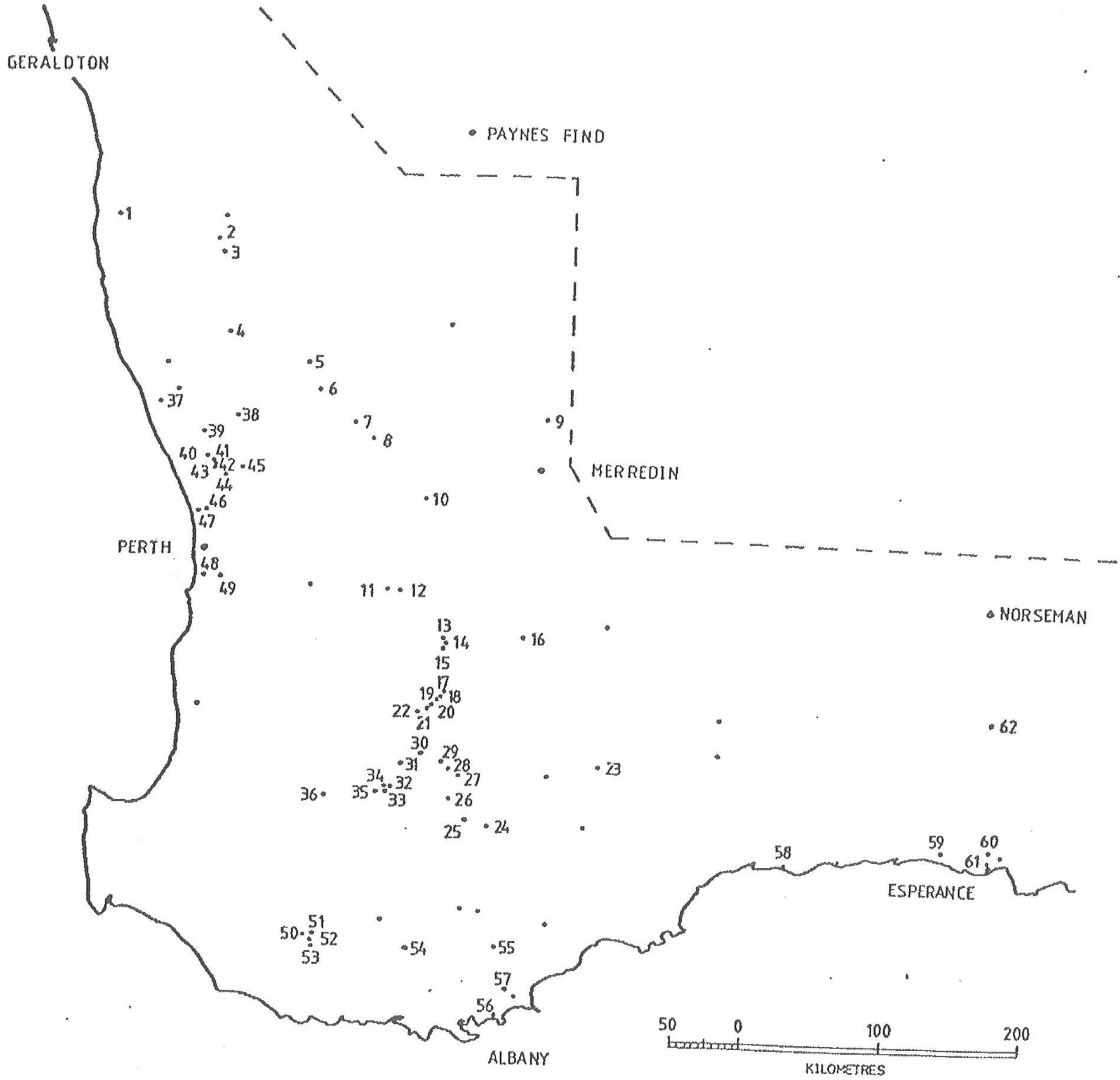


FIGURE 9. Location of Gauged Lakes.

Appendix 94 continued. Extracts from Lane & Munro (1980).

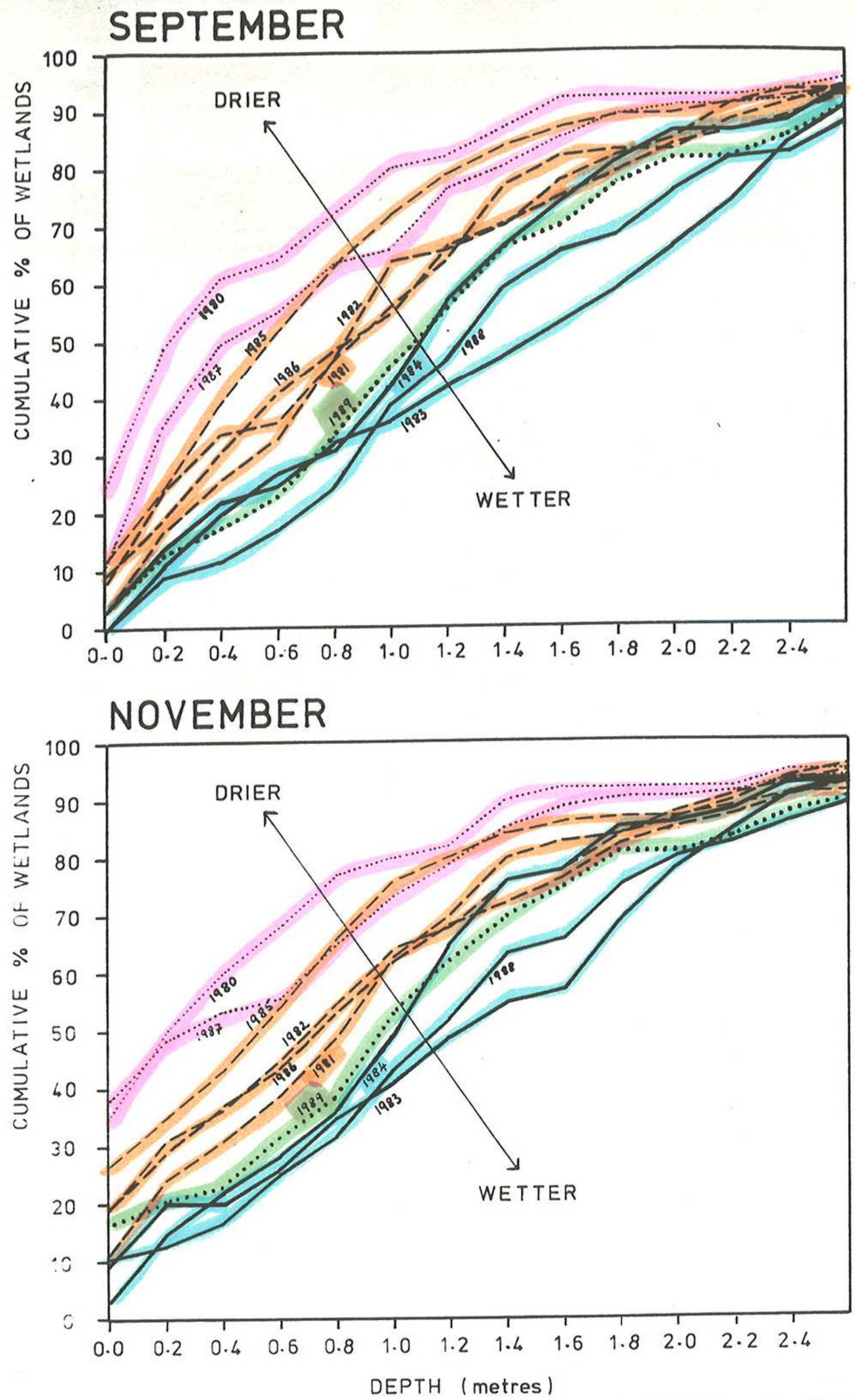


FIGURE 4. CUMULATIVE PERCENTAGES OF WETLAND DEPTHS.

Water levels of a sample of wetlands in south-western Australia have been measured in September and November each year (i.e. during the duck breeding season) since 1980.

The graphs above show that water levels in September and November 1989 (••••••••) were comparable with those of 1984 when a Full (▬▬▬) shooting season was declared (84/85), and marginally above those of 1981 when a Restricted (▬ ▬ ▬) season was declared.

Statistical tests (paired t-tests) show that 1989 water levels were not significantly different from those of 1984 or 1981.

Appendix 95. Extracts from Lane (1989) *Consideration of possible duck shooting seasons in Western Australia in 1990.* Unpublished report for Director of Nature Conservation, Western Australian Department of Conservation & Land Management. 16pp.

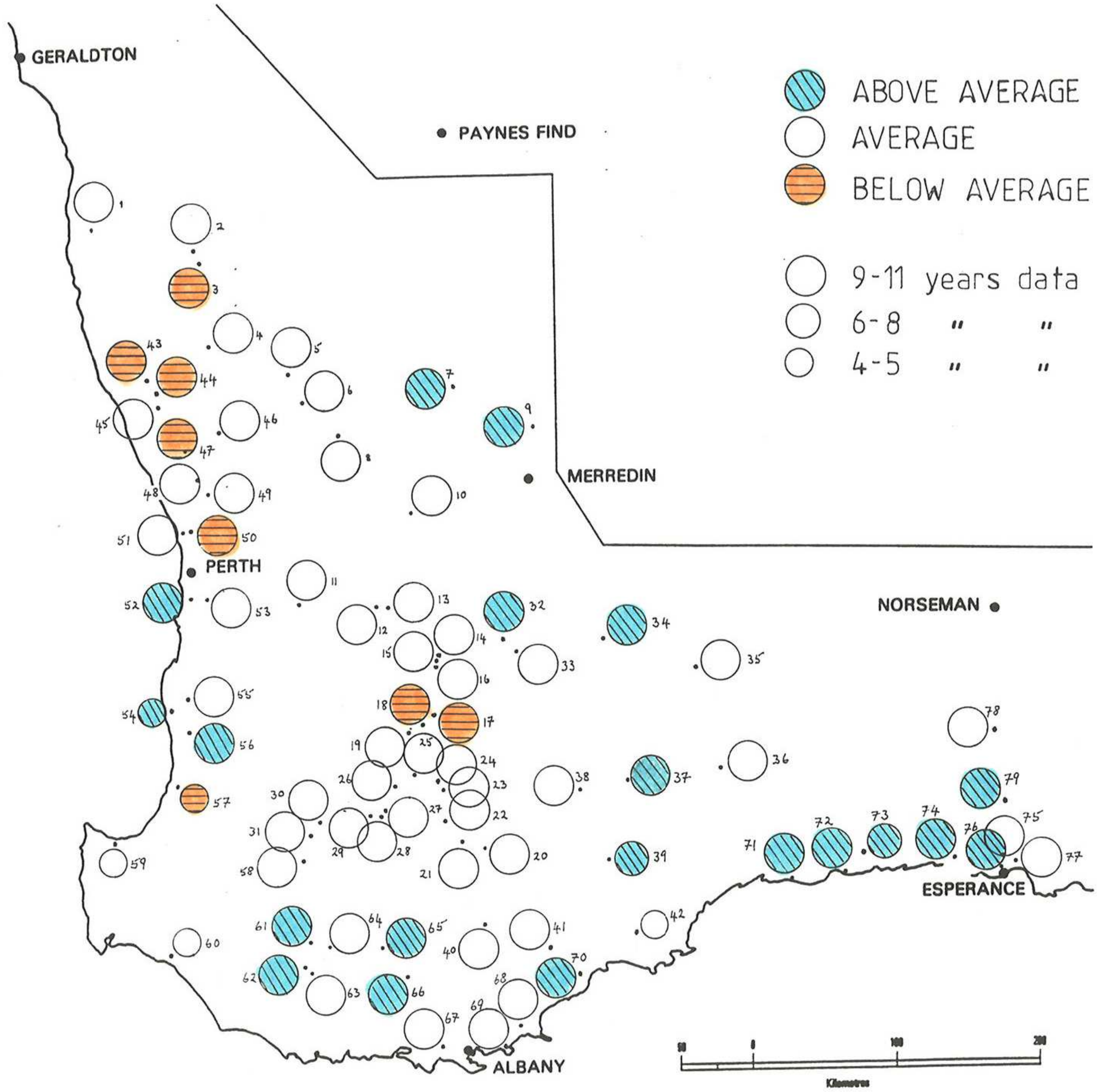


FIGURE 5. WATER LEVELS OF A SAMPLE OF SOUTH WEST WETLANDS IN SEPTEMBER 1989.

For the purposes of the above illustration "average" has been defined as the middle 50% (i.e. 25%–75% inclusive) of recorded values. Actual depths are not indicated.

Numerals refer to wetland names. These are provided in Appendix 1, together with depths.

Appendix 95 continued. Extracts from Lane (1989).

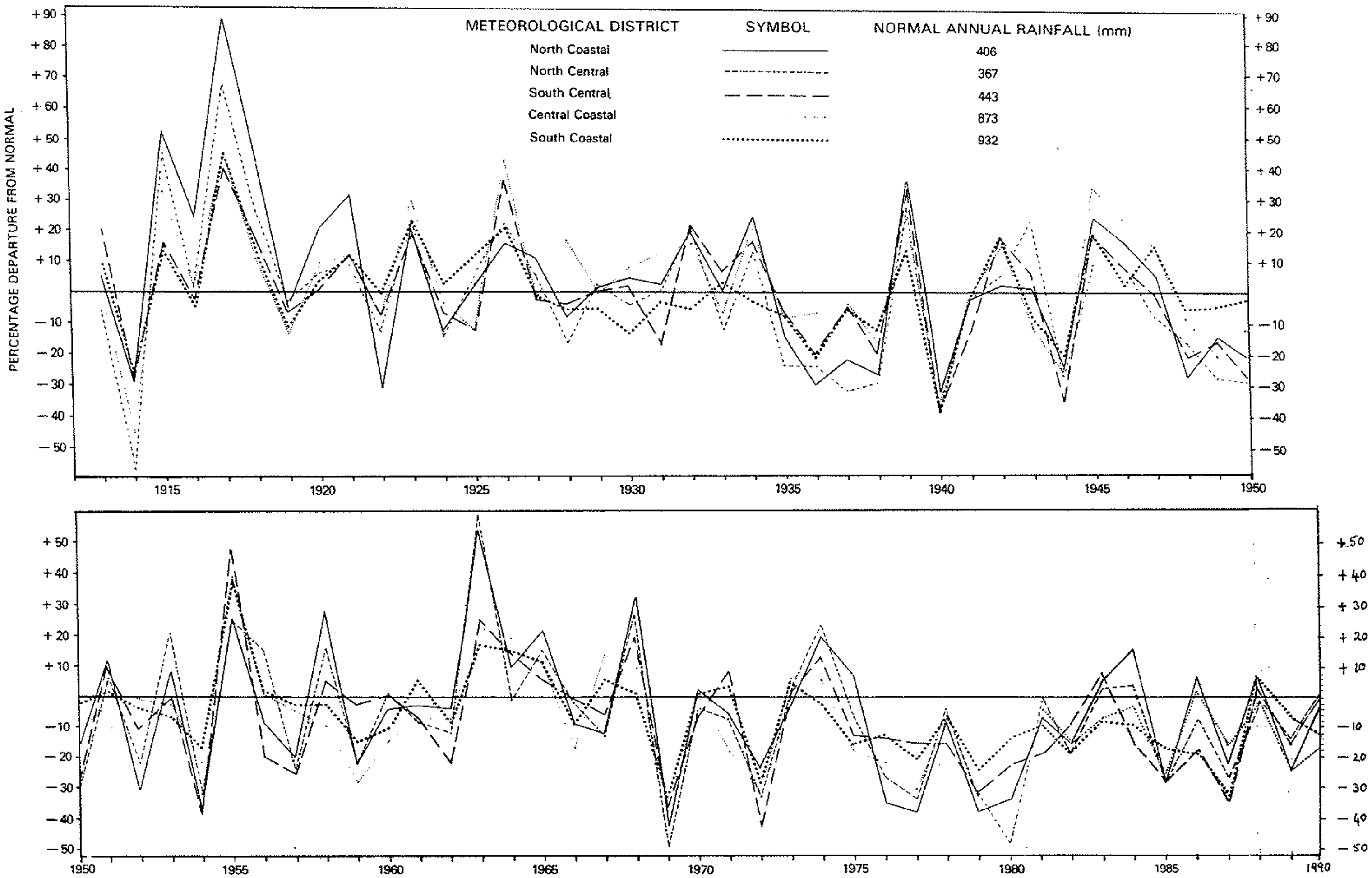
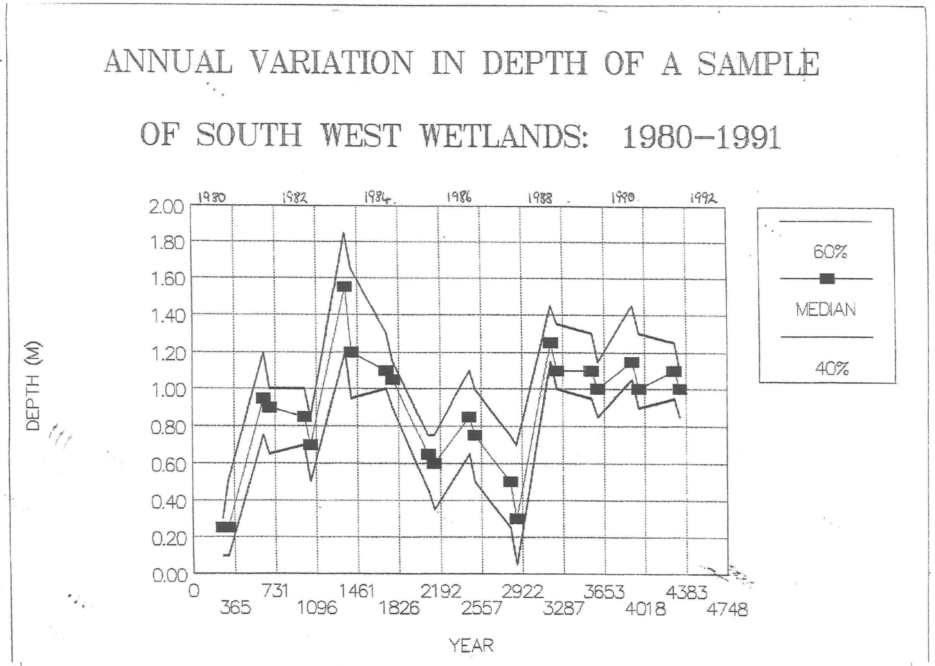
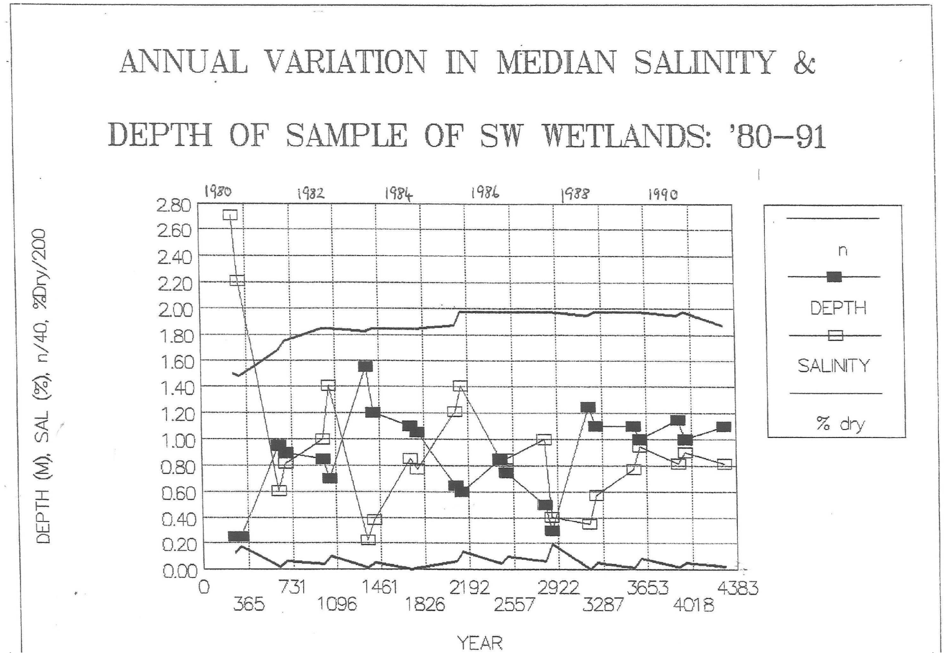


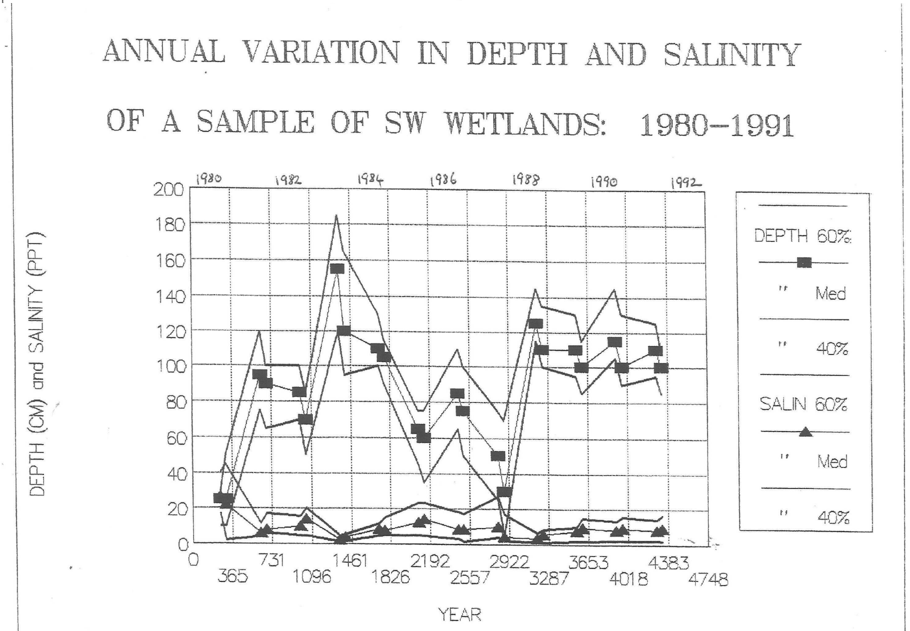
FIGURE 1. Rainfall recorded annually in each of the Meteorological Districts of the south-west, from 1913 to 1990 expressed as percentage departures from normal.

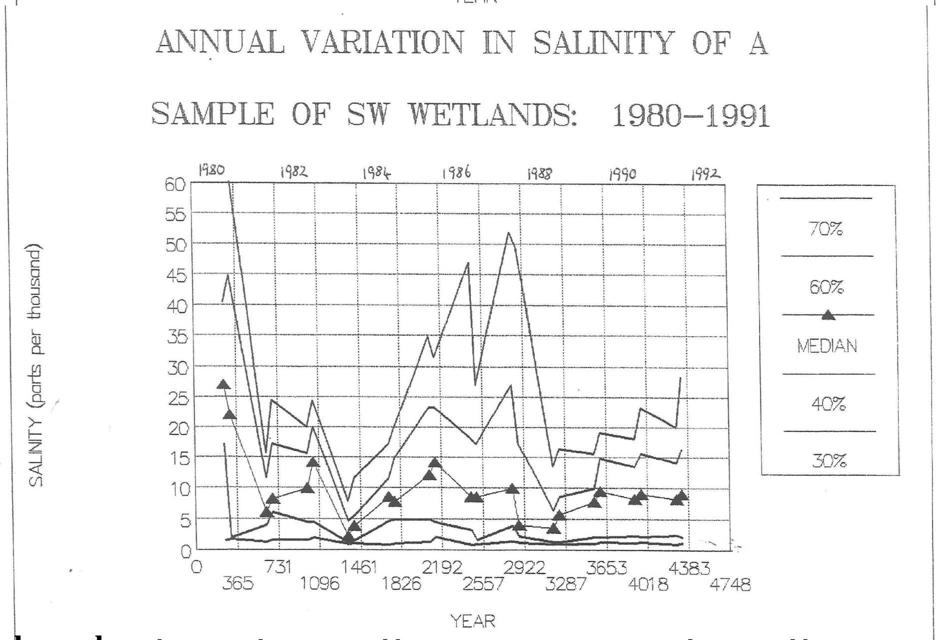
Percentage departures from normal for 1990 are based on January-October rainfall.
Normal rainfalls for this period are 93-96% of annual totals.

Appendix 96. Extract from Lane (1991) ***Consideration of a possible duck shooting season in the South West and Eucla Land Divisions in 1991.*** **Unpublished report for Director of Nature Conservation, WA Department of Conservation & Land Management. 15pp.**

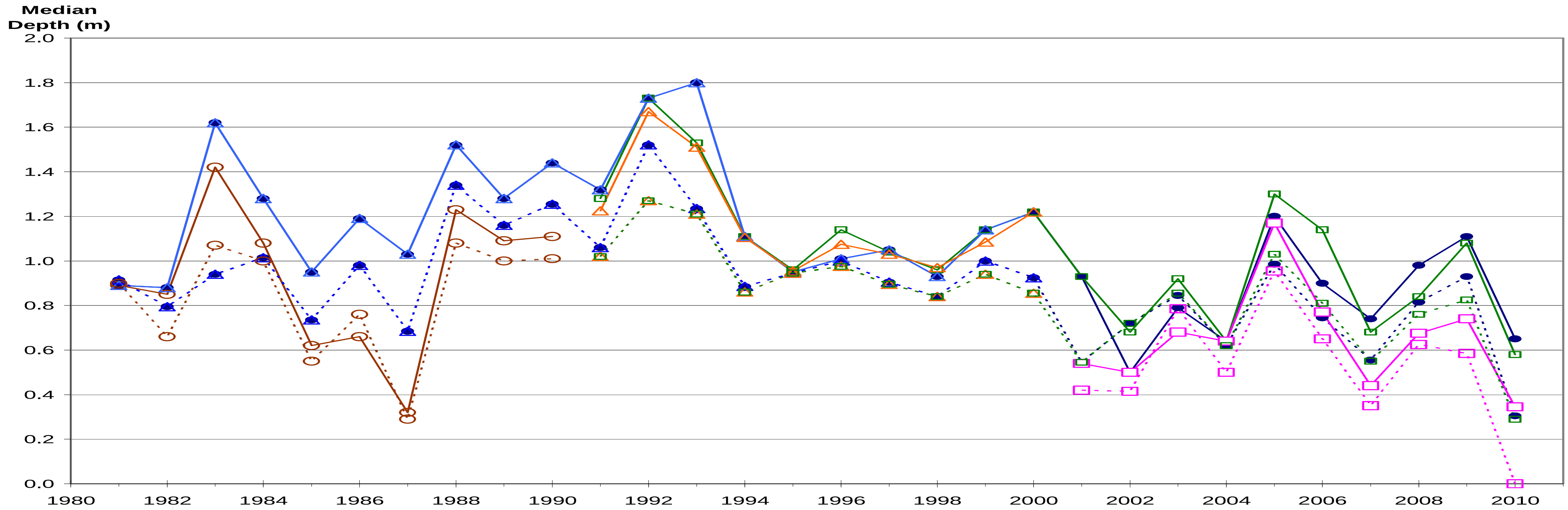


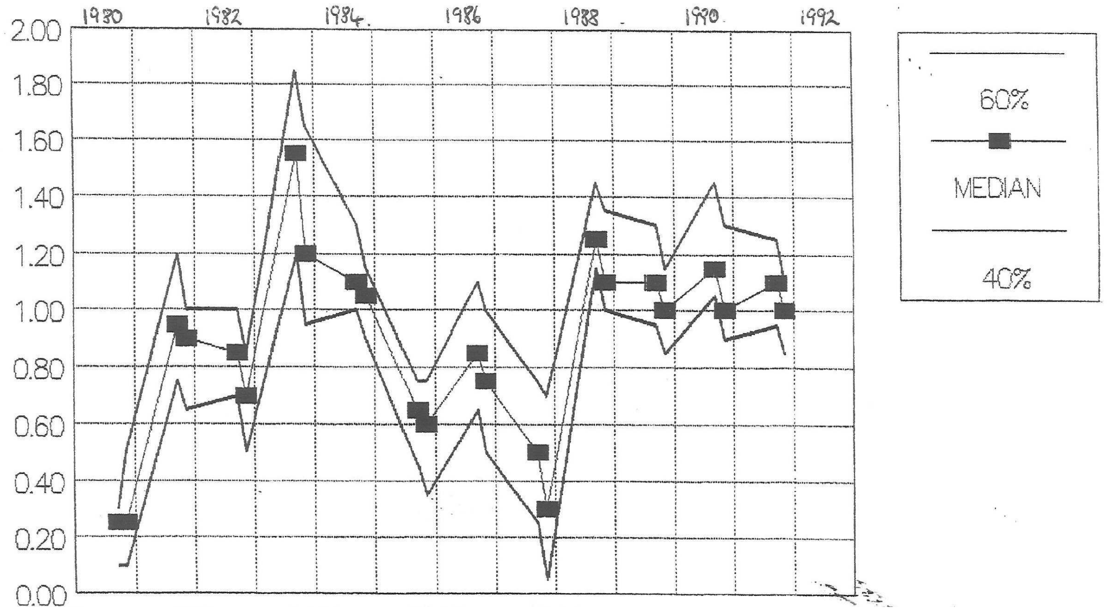






Appendix 97. Collection of Sept & Nov 1980-1991 depth and salinity trend graphs. These graphs, prepared by JLane in 1991, were re-discovered by JL late in the process of preparing the 1981-2010 depth trends report. Note the very low median depths in 1980. Note also the 'n' values (number of wetlands) in the top right hand graph. These range between ≈ 59 (Nov 1980) and ≈ 79 (most Seps & Novs 1985-1990). The y axis values of this top right hand graph are n/40.





Appendix 98. Comparison of 1981-2010 and 1980-1991 median depths.

The 1981-2010 graph **(above)** is a combination of Fig. 1 (Sept depth medians) and Fig. 2 (Nov depth medians) of this report. In this graph the number (n) and composition of wetlands is constant in each of the 12 series. The 'n' values of the six series incorporating the period 1981-1990 range between 69 and 21. The 'n' values of the eight series incorporating the single year 1991 range 36 to 21.

The 1980-1991 graph **(below)** is from Appendix 97. In this graph of Sept & Nov depth medians each median value is of all wetlands (n) monitored that month and the composition of wetlands is somewhat variable from month to month. The 'n' values (by eye from the top right chart of Appendix 97) in the period 1980-1991 range between ≈ 79 and ≈ 59, with the lowest values being in 1980.