Estimation of Irrigation Accession Volumes for the Berri, Cobdogla, Renmark and Chaffey Irrigation Districts

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1 Introduction

The Department for Environment, Water and Natural Resources (DEWNR) contracted Laroona Environmetrics to review accessions[1] from irrigation applications to the regional groundwater in the Cobdogla, Berri, Renmark and Chaffey Irrigation Districts. The accessions are an input into the regional groundwater model for estimating salt loads to the River Murray. This study is similar to previous studies undertaken for DEWNR and its predecessors (Meissner, 2014, 2012, 2011a,b). The agreed tasks of the study were:

- Review historical data on irrigated area, irrigation application rates, volume of irrigation water pumped, volumes of drainage water collected by the Comprehensive Drainage Schemes (CDS), rainfall data and irrigation efficiency values used to estimate accessions to the regional groundwater;
- Construct worksheets to estimate the volume of applied water draining beyond the root zone of irrigated crops for each of the irrigation districts;
- Provide the spreadsheet of interim estimations of accessions for review by DEWNR groundwater modellers; and
- Provide a report of the accession study.

The Berri – Renmark groundwater model covers the Central Irrigation Trust (CIT) areas of Cobdogla, Berri and Chaffey and the Renmark Irrigation Trust Area. Figure 1 shows the map of these irrigated districts.

2 Description of data and methodology

Microsoft Excel® spreadsheet files were supplied containing data for irrigated areas and consumption (irrigation) volumes for years for which the data was measured or estimated (*Berri-Renmark_Consumption_CropArea _data_20150617.xlsx*, *Berri-Renmark_Consumption _data_20150708.xlsx*, textitBerri-Renmark_CropArea _data_20150623.xlsx). These data were then transferred to a new spreadsheet that contained templates for calculating the volume of accessions from the application of irrigation water to horticultural crops (*Irrigation Accessons.xlsx*). Monthly rainfall data for Renmark (Station ID=024003), Lyrup (Station ID=024008),

[1] **Accessions are defined as the volume of water draining beyond the rootzone of irrigated crops that eventually percolates to the groundwater. Accessions volumes are not necessarily equal to groundwater recharge volumes. The presence of aquitards, lateral spread of the accession front and water held in the geological layers above the aquifer are some factors that affect the recharge volume**

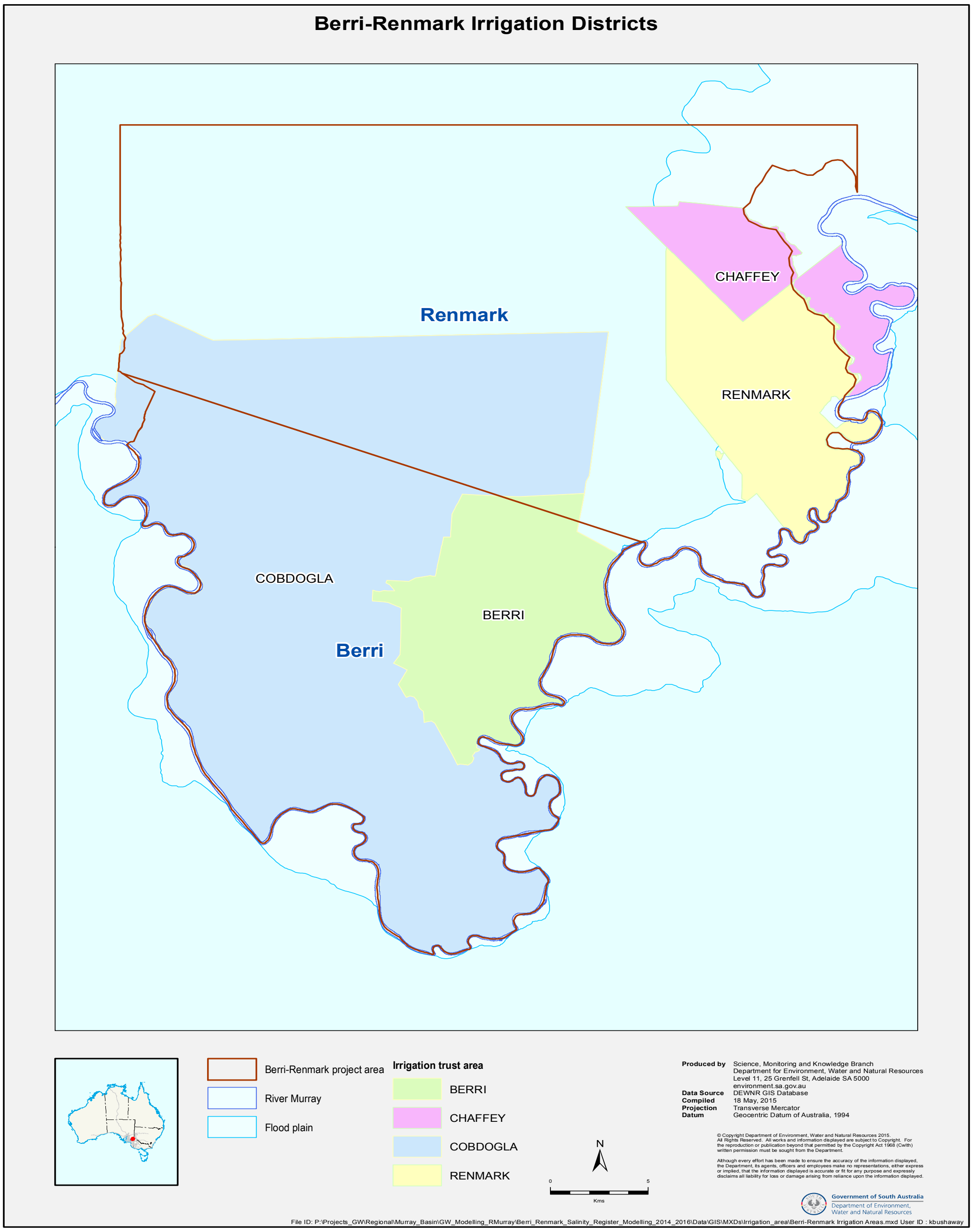

Figure 1: Map of the Cobdogla, Berri, Renmark and Chaffey Irrigation Districts for which irrigation accessions were calculated. **Note** Cobdogla includes the Loveday area (mostly highland) and Chaffey – the Cooltong area (mostly flood-plain)

Berri (Station ID=24025), Barmera (Station ID=24001), and Kingston-on-Murray (Station ID=24008) were downloaded from the Bureau of Meteorology (URL:http://www.bom.gov.au/climate/data/index.shtml)

Renmark Irrigation Trust provided four Excel® files containing records of *hours* drainage caisson pumps were operated, *power consumption* and *volumes pumped* covering the period October 1998 to May 2015.

2.1 Irrigated Areas

Area data supplied in the spreadsheet *Berri-Renmark_CropArea _data_20150623.xlsx* were copied to the respective worksheet in the Excel® file *Irrigation Accessions.xlsx*. Years for which there was no data, area was calculated by linear interpolation between the years for which there were measured data. Estimated values are shown by coloured cells in the Excel® worksheets that accompany this report.

2.2 Irrigation Application Volumes

Records of pumped volumes for the period 1992 – 2013 for each of the irrigation districts were supplied in the file *Berri-Renmark_Consumption_ data_20150617.xlsx*. Before that period, pumped volumes were estimated by the following formula (see 2.3 on 3):

$$pumped = area \times appl\_rate \pm \rho \tag{1}$$

where **pumped** is measured or estimated water volume applied (ML/ha), **area** was either measured or estimated irrigated area (see 2.1 above), **appl_rate** was inferred or measured application rate (ML/ha) (see 2.3 below) and ρ a random component to mimic variability.

2.3 Application Rate

Historically, application rates in the late 19th and early 20th centuries are unknown. I chose an irrigation application rate of 11.0 ML/ha for the period up to 1931, 10.5 ML/ha for the years between 1932 and 1970 and 9.5 ML/ha from 1971 until 1991, after which there are measured data. These rates are within the range from previous studies (Meissner, 2014, 2012, 2011a,b) allowing for variation in crop mixtures. When application volumes were measured application rates were calculated by the following formula:

$$appl\_rate = pumped/irr\_area \tag{2}$$

where **appl_rate** rate of application of irrigation water (ML/ha), **pumped** is measured or estimated water volume applied (ML/ha) and **irr_area** was either measured or estimated irrigated area (ha).

2.4 Irrigation Efficiency

Irrigation efficiency values used in the calculations were the same as those from the Loxton – Bookpurnong Report (Meissner, 2011a), which values were derived from Adams and Meissner (2009). The same irrigation efficiency values were applied to all districts. A value of 55% irrigation efficiency was applied to prior to 1940. From 1940 onwards, irrigation efficiency values were: 60% from 1941 – 1960; 65% from 1961 – 1990; 70% from 1991 – 1994; from 1996 – 2000 it was assumed to be 75% and from 2001 onwards 80% was adopted – the changes due to improved irrigation technology and equipment, improved irrigation management skills and knowledge of irrigators.

2.5 Rainfall

Rainfall records for Renmark and Chaffey were those used in the 2014 study of Lyrup, Simarloo, Pike and Murtho (Meissner, 2014) updated until 2014. Berri records where a merge of the Berri, Lyrup and Renmark rainfall data and for Cobdogla, the Barmera and Kingston-on-Murray records were merged. The Renmark rainfall data was used for Chaffey. Where there were missing data, the values were imputed for each of the months for which data was not recorded. The missing monthly values were estimated by sampling without replacement from the respective non-missing monthly data for each of the respective stations. Rainfall data is in the file *rainfall.xlsx*

From the monthly data, annual totals were calculated. The annual totals were then pasted into the respective district worksheets to match those years when irrigation commenced in each district until 2014. Rainfall (mm) was converted to a volume by the following formula:

$$Rain\ Volume \ = \ Rain(mm) \times area/100 \qquad (3)$$

where 100 is the conversion constant from mm to ML.

3 Assumptions in Estimating Irrigation Efficiency and Application Rate

Two quantities were required to be estimated either from personal knowledge and experience or from the scant available published data. These quantities were: (i) Application rate in units of ML/ha and (ii) Irrigation efficiency a dimensionless quantity between 0 and 100%. Application rates were not available from the late 1890s when irrigation began until measured pumped volumes and area were available. Irrigation efficiency was estimated using historical information of irrigation practices until values were estimated and published from the mid 1970s until the present (Adams and Meissner, 2009).

3.1 Floodplain and Highland

The Cobdogla, Berri and Chaffey irrigation districts had both a floodplain and highland component; Renmark irrigation occurred only on the floodplain. The groundwater levels were of the order of 2 – 5m below ground surface on the floodplain and for the highland likely 10 – 20m. Hence there would have been a difference in the time the wetting front reached the groundwater on the floodplain compared to the highland. Estimates of irrigation accessions made no distinction of topography because the information provided did not differentiate between floodplain and highland.

3.2 Comprehensive Drainage Schemes

All the irrigation districts had water tables rising to 2m or less of the ground surface, ten to 15 years after irrigation commenced. Comprehensive drainage schemes were installed to drain the soils to lower the watertable below 2m or more. The drainage pipes delivered the drainage water to sumps or caissons from which the water was pumped to disposal basins. Estimates of the amount of water collected in the Loxton Irrigation Area were 12 - 15% of irrigation water draining beyond the root zones of horticultural crops (Meissner, 2011a). On the floodplain, because the groundwater was close to the surface, the CDS was likely to intercept the groundwater as well as any water draining beyond the roots of the horticultural crops. It is unknown how much of the groundwater was intercepted compared to irrigation drainage. Hence, the assumption is that the volume captured by the CDS was all due to intercepted irrigation drainage.

Renmark Irrigation Trust provided records of hours drainage pumps were run and the power used for the period October 1998 - until May 2015. There were data from 13 caissons, some of which the volume of drainage water was metered.

These records were examined, corrections made and the power consumption and volume pumped for caissons 1,2,3,4 and 6 were summed for each year after 2003. The results were then plotted and a line was fitted (See Figure 2). The equation of the line was then used to estimate the volume of drainage water pumped from each of the 13 caissons. For each year, the volumes from each caisson were summed to give a total annual totals for the Renmark IAthat was pumped to the Noora Disposal basin. The annual CDS volume was about 11.5% of water draining beyond the root zone of horticultural crops in 1999 declining to about 5 – 6% by 2014. These figures were then used for each of the districts. Before 1999, it was assumed the CDS volumes peaked at about 12% and extrapolated back to when the schemes commenced usually between 10 – 15 years after irrigation commenced. The derived percent volumes were similar to that calculated for the Loxton IA (Meissner, 2011a).

3.3 Miscellaneous Quantities

All of the irrigation districts had irrigation water delivered by channels that followed the contour of the land. Initially, these channels were earthen but from the mid 1930s these channels were replaced by concrete-lined ones. The channels lost water either by spillage at the end of the channel networks or over the sides (*spillage*) or by seepage through the joints or cracks in the channel (*transmission losses*). The earthen channels lost substantially more water through seepage into the clay soil compared to the concrete channel and a value for these transmission losses was set at 50% higher than for the concrete–lined channels. The values for spillage (5% of pumped volumes) and transmission losses (15% of pumped volumes) were adopted from those cited in the Loxton report (Meissner, 2011a). The various districts replaced the concrete channels with pipes from the 1980s (Berri, Chaffey and Renmark) to the mid 2000s (Cobdogla). Hence these losses were effectively eliminated from that time onwards.

4 Calculation of Accession Volumes

In the Mallee and riverine landscapes (floodplains), water draining beyond the root zone of either perennial or annual horticultural crops eventually finds its way to the underlying groundwater. The amount of drainage water is determined mainly by the total applied water volume the proportion of which is determined by the efficiency of irrigation. Some of the applied water is from rainfall. Rainfall is usually not 100% effective due to evaporation from plant and soil surfaces (Dastane, 1978) or from runoff. In the Riverland, 60% of rainfall has been deemed to be effective (T. Adams pers. comm) and this was the value used

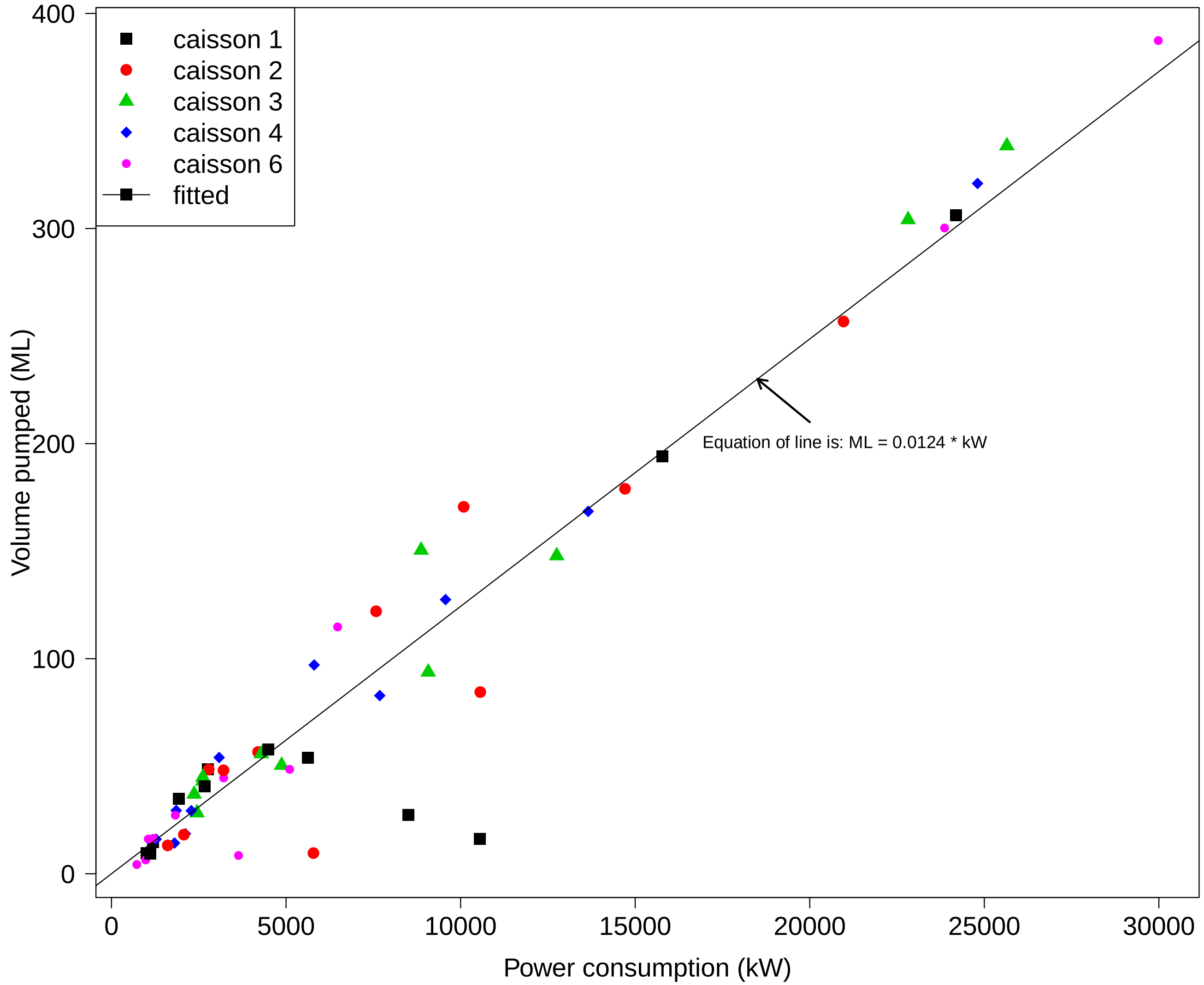

Figure 2: Power consumption (kW) versus annual drainage volumes (ML) pumped for caissons 1,2,3,4 and 6 in the Renmark Irrigation Trust area from 1999 – 2014. The line was fitted by least squares regression

as being effectively applied to crops. The effective rainfall value was added to the applied irrigation volume (Meissner, 2011b). The amount of applied water draining beyond the root zone is that amount not used by the plants. Where there were spillage and drainage losses, the volume draining beyond the root zone of plants was calculated as for the Loxton – Bookpurnong study(Meissner, 2011a).

Hence, the volume draining past the root zone was estimated as:

$$Accession\ Volume = tot\_appl \times (1 - IE) \tag{4}$$

where **IE** is irrigation efficiency, **tot_appl** is total application volume including rainfall, spillage and transmission losses.

5 Discussion

Renmark was the first irrigation district on the River Murray in South Australia to be developed by the Chaffey Bros. commencing in 1897. In the early 1900s the SA Government passed an act of parliament establishing the Renmark Irrigation Trust. Berri Irrigation Area was established in 1910, followed by Cobdogla in 1912, then Chaffey (1922). After most of the irrigation areas where rehabilitated — commencing in the 1960s and completed by 2000 — by replacing the concrete channels with pipes, the day-to-day management of the irrigation districts of Berri, Cobdogla and Chaffey was vested in the Central Irrigation Trust. The Renmark Irrigation Trust(RIT) managed its own irrigation area.

Because of the lack of historical records on volumes of water pumped from the R. Murray, the volumes are estimated from historical information on the depth of water applied at each irrigation and the number of irrigations per season. There is some variation between the various areas for which irrigation accessions have been calculated ((Meissner, 2014, 2012, 2011a,b; Adams and Meissner, 2009)). The rates for the four irrigation districts in this report are the same for all of them and are outlined in sections 2.1, 2.2 and 2.3 above. Hence, accessions rates (ML/ha) are similar and differ only in the simulated annual variation. Where measured data was available from 1992 onwards, there is little variation between the districts (see 3).

Accession rates were initially high at 5.7 ML/ha – about 47% of total applications – reflecting estimated high application rates of irrigation, low irrigation efficiency, spillage and transmission losses. As application rates declined and irrigation efficiency improved and delivery infrastructure rehabilitated from mid 1980s onwards, the accession rates declined at an average of 0.033 ML/ha/yr. From 1992 onwards, when records were available the average accession rate was 1.6 ML/ha reflecting improving irrigation efficiency and the effects of the 2005

– 2010 drought. Since 2010, there has been a small increase in accession rate. This reduction in irrigation accessions is reflected in the decline in the volume of water captured by the CDS shown by the data of RIT.

Whilst application rates have remained relatively constant over the last 20 to 30 years with a decline during and after the drought years of 2005-2010 for all districts, total accession volumes have declined over this period reflecting improved irrigation practices and the effects of drought during which allocations were reduced and some land ceased to be irrigated. The picture presented in this report is consistent with the general picture of other areas that have been reported on (Meissner, 2014, 2012, 2011a,b; Adams and Meissner, 2009).

5.1 Comments of Estimated Accession Volumes

The irrigation accessions volumes are best estimates given the level of understanding of irrigation in the Riverland and by the quality and quantity of measured data of area, pumped volumes and application rates. It would be unwise to give an estimate of the error in the data before 1992. At the start of irrigation for each of the districts, the estimated irrigated areas given in the spreadsheet file was considered unrealistic and an area of between 30 – 50 hectares was assumed as a reasonable starting point for area initially irrigated.

An explanation of the important parameters determining irrigation accession can be found in the Lyrup, Simarloo, Pike and Murtho irrigation accession report of Meissner (2014).

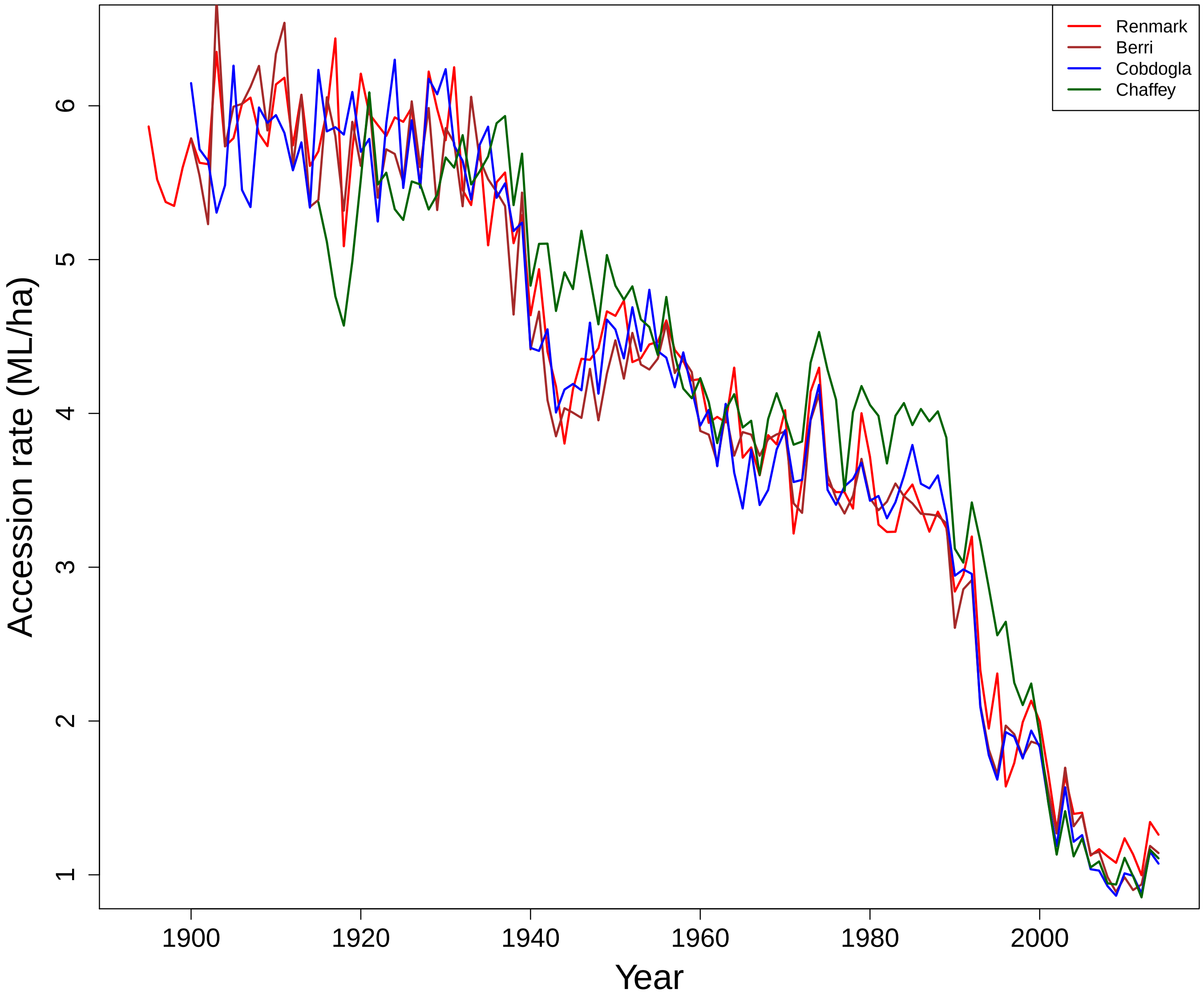

Figure 3: Annual variation of irrigation accessions rate (ML/ha) for each of the irrigation districts of Cobdogla, Berri, Renmark and Chaffey from commencement of irrigation until 2014.

6 Bibliography

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Appendix A Excel® Spreadsheets

The template containing the district worksheets of calculations to estimate water draining beyond the rootzone is the file *Irrigation Accessions.xlsx*. Also attached is the file *rainfall.xlsx* containing the rainfall data.

Appendix B Cobdogla

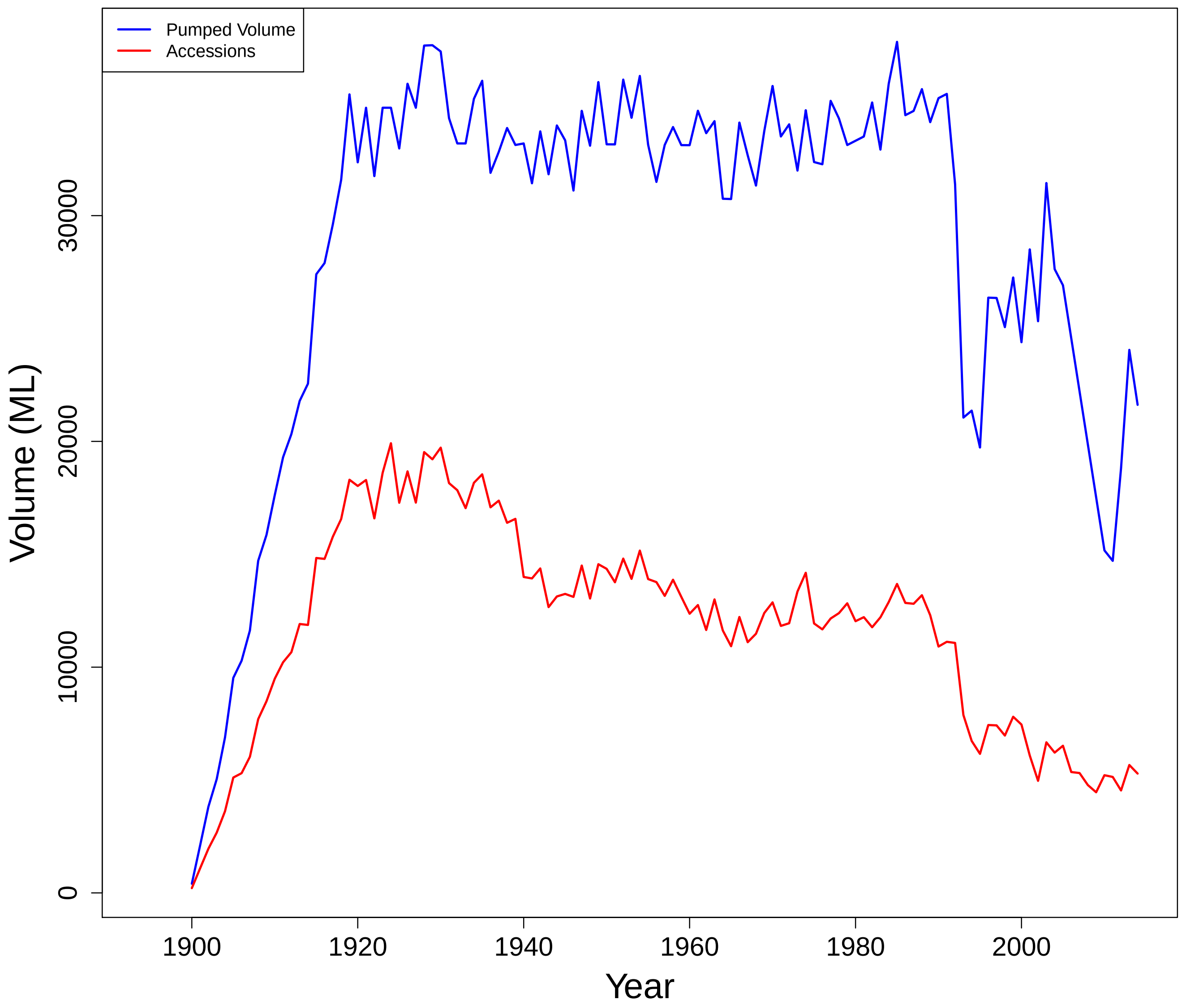

Figure 4: Pumped irrigation and accession volumes for the Cobdogla Irrigation district 1900 – 2014

Appendix C Berri

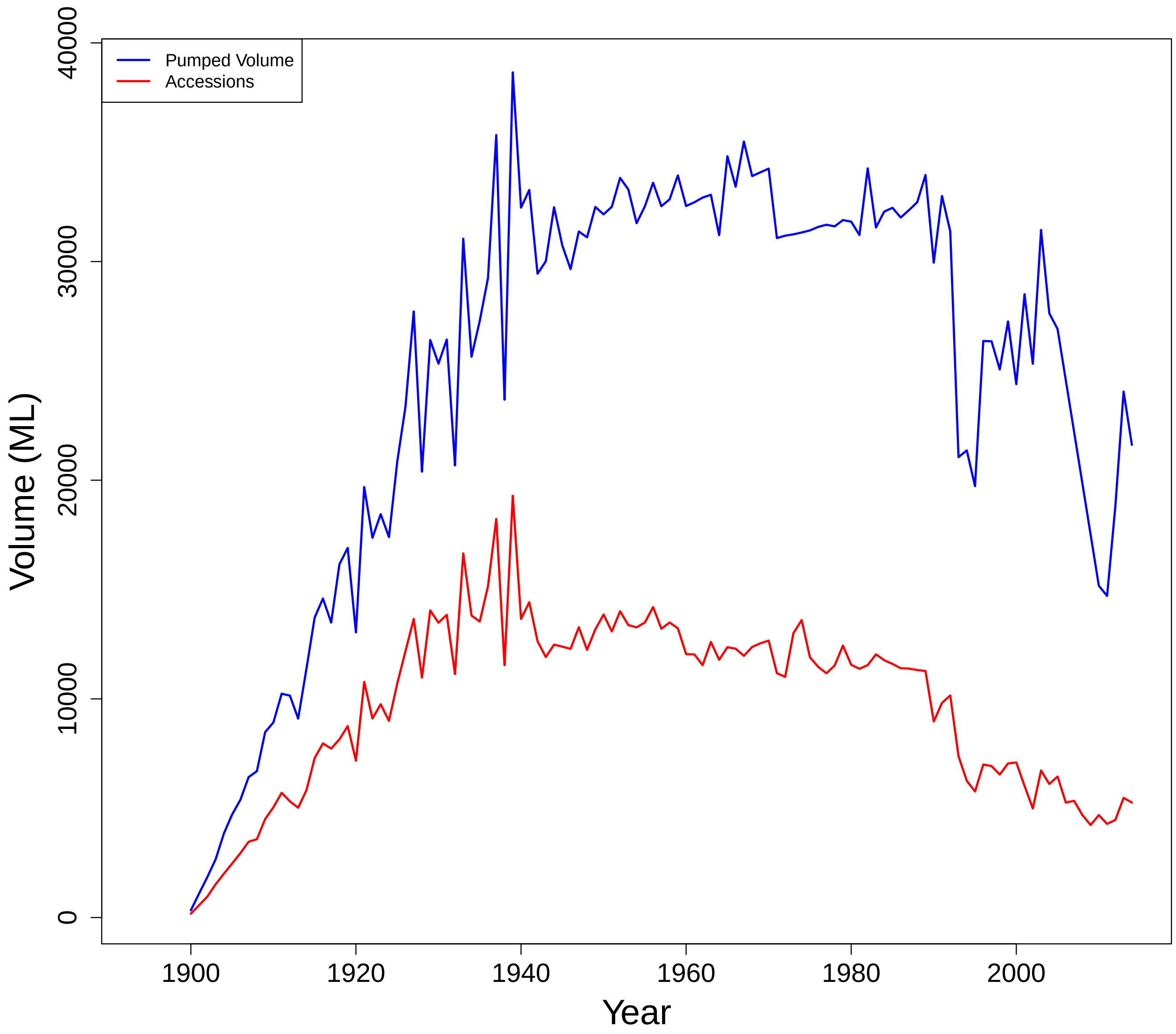

Figure 5: Pumped irrigation and accession volumes for the Berri Irrigation district 1900 – 2014

Appendix D Renmark

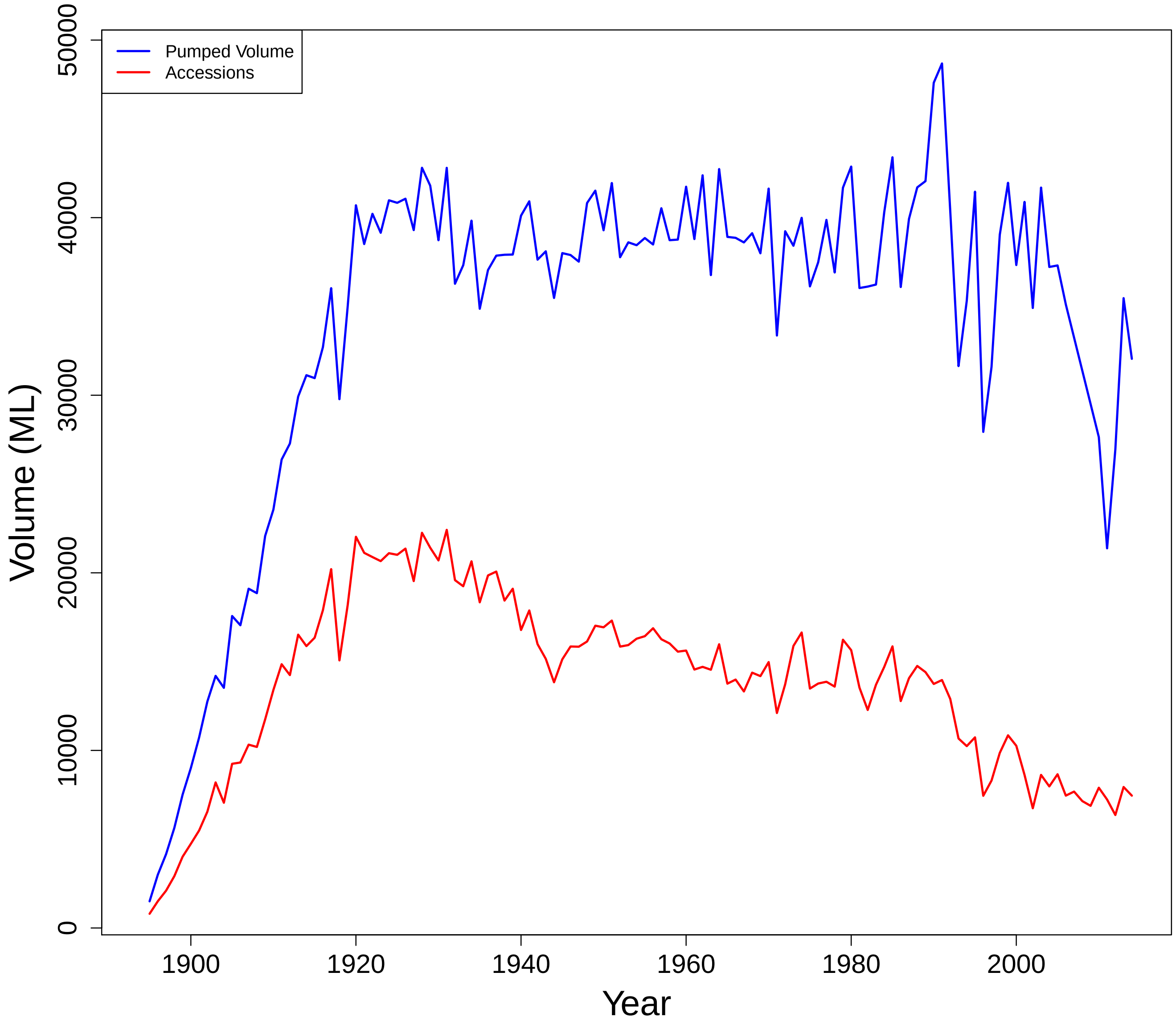

Figure 6: Pumped irrigation and accession volumes for the Renmark Irrigation district 1900 – 2014

Appendix E Chaffey

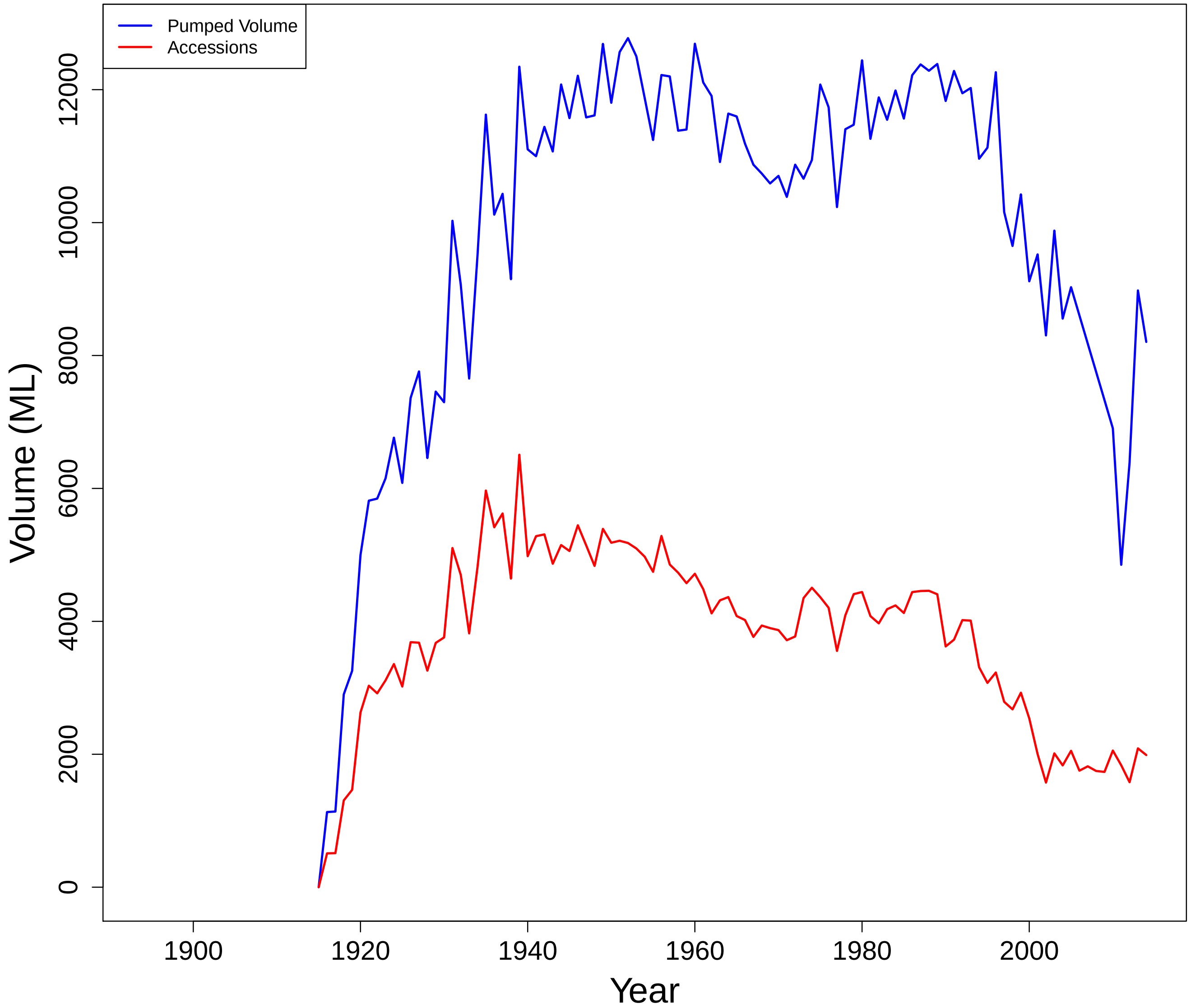

Figure 7: Pumped irrigation and accession volumes for the Chaffey Irrigation district 1915 – 2014