PLANNED UPGRADE OF NIWA'S HIGH INTENSITY RAINFALL DESIGN SYSTEM (HIRDS)

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ABSTRACT

Statistics of extreme rainfall play a vital role in engineering practice from the perspective of mitigation and protection of infrastructure and human life from flooding. While flood frequency assessments, based on river flood flow data are preferred, the analysis of rainfall data is often more convenient due to the finer spatial nature of rainfall recording networks, often with longer records, and potentially more easily transferable from site to site. Rainfall frequency analysis in New Zealand as a design tool has developed over the years from daily rainfall frequency maps to a web based tool. This paper briefly describes historic methodologies and outlines the planned upgrades for HIRDS Version 4. The aim of the upgrade is to search out and expand New Zealand's rainfall dataset to improve coverage, include recent storms, and include historic paper records. The proposed upgrade will carry out analysis to extend the average recurrence interval to the 250 year return period, provide areal reduction curves and temporal patterns for design storms. Other features will include the ability to enable engineers to download maps of areas of interest for specified rainfall duration and frequency from a web site, and provide a comprehensive list of the rain gauges used.

PRESENTER PROFILE

Graeme measured rainfall transects across the Southern Alps, discovering annual rainfalls of 12 metres. He has carried out design flood studies for major hydropower developments. He was the hydrologist for eighteen years at Environment Canterbury involved in water management. At NIWA one of his projects is upgrading HIRDS.

1 INTRODUCTION

High intensity rainfall statistics are of prime importance in flood estimation as well as engineering construction work where allowance has to be made for the disposal of water after storms. For these types of use of rainfall statistics it is desirable to be able to express in probabilistic terms the likelihood of various amounts of rainfall for given durations. The inherent difficultly in providing these statistics is the method of estimating the return periods, such as the 100-year return period rainfall depth, for a duration from only a record of 10 years. This is overcome by using data records from a large number of rain gauges with methods to interpolate between gauges. This paper provide a history of such extreme rainfall estimation methods in New Zealand (e.g., High Intensity Rainfall Design System, "HIRDS", Thompson, 1993) and describes the data samples and enhancements planned to be included in an upgrade of HIRDS.

2 CHRONOLOGY OF NEW ZEALAND METHODS

2.1 SEELYE (1947)

Seelye (1947) used data from 289 manually read daily (9 am) rain gauges and one automatic rain gauge (Kelburn, Wellington). The daily manual records included 91 with over 40 years records, with 99 extending over 30 years and another 99 of shorter duration. Based upon the Kelburn automatic record the annual maximum daily manual rainfalls were converted to 24 hour maximum totals by increasing the 9 am annual maximum by 12 to 13%. The Gumbel (1943) frequency distribution was used to estimate up to 100-year return periods of 24-hour duration rainfall amounts for each rain gauge and were contoured manually.

2.2 ROBERTSON (1963)

Robertson (1963) used 44 automatic rain gauges with data record lengths of at least 9 years, while the manually read rain gauges totalled 470 with at least 20 years of data, which also provided 24, 28 and 72 hour duration statistics. The conversion factors from daily manual rain gauges read each day at 9 am to maximum 24, 48 and 72 hour rainfall totals were 1.13, 1.06 and 1.05, respectively. Robertson also used the Extreme Value Type 1 (EV1) or Gumbel distribution to estimate frequencies of annual maximum storm rainfalls. Robertson produced a map of rainfall depth of known duration and frequency at any point in New Zealand. The methods and results were similar to those of Seelye (1947).

2.3 TOMLINSON (1980)

With longer records available, Tomlinson (1980) updated the rainfall estimates of Robertson (1963). Tomlinson used 180 automatic rain gauges and 940 manually read daily rain gauges. The record length stipulations were at least 5 years of record for automatic rain gauges and 10 or more years of record for the manually read gauges. The conversion factors from daily manual rain gauges read each day at 9 am for 24, 48 and 72 hour rainfall totals were 1.14, 1.07 and 1.04 respectively.

Tomlinson used the Extreme Value Type 1 (EV1) or Gumbel distribution to estimate frequencies of annual maximum storm rainfalls, documenting some rainfall values that were better fitted by an extreme Value Type II (EV2) distribution for the annual maxima analysed. These values were defined as "outliers" and removed from the analysis, and the EV1 distribution was then acceptable for the remaining data.

Tomlinson developed four maps of rainfall estimates (mm) for 10 minute, 30 minute, 6-hour and 24-hour duration, each for a 5-year return period, and conversion tables for rainfall estimates of other durations and return periods.

2.4 THOMPSON (1992) (HIRDS VERSION 1)

Thompson (1992) converted Tomlinson's 1980 maps, graphs and tables into a computer based procedure where the user entered location coordinates to obtain a table with ten durations from 10 minutes to 72 hours and up to the 100-year return period. This was the first version of the High Intensity Rainfall Design System, "HIRDS".

2.5 PEARSON AND HENDERSON (1998)

Pearson and Henderson (1998) looked in detail at the previous analysis by Tomlinson (1980) and in particularly at the “outliers” removed from the EV1 (Gumbel) frequency analysis. They used daily rainfall records from 1933 rain gauges to obtain the 24-hour duration annual maximum series, and hourly and 6-hourly annual maxima from just over 150 automatic rain gauges. They fitted the Generalised Extreme Value (GEV) distribution to the annual maximum series, using the method of L-moments (Hosking 1990).

Pearson and Henderson (1998) concluded that for hydrological design that deleting “outliers” and using the EV1 distribution leads to underestimation of design storm rainfalls for many New Zealand regions. These included all of the drier eastern regions of New Zealand, and Southland, Taranaki and Auckland, where they found annual maxima of 24-hour rainfalls tend toward the Extreme Value Type II (EV2) distribution.

2.6 THOMPSON (2002) (HIRDS VERSION 2)

In an update of HIRDS Thompson (2002) used 682 automatic rain gauges with a data length of at least 9 years, while the manually read rain gauges totalled 2375 with at least 20 years of data, these were used for the 24, 28 and 72 hour statistics. In this revision a large increase in data had become available since maps were last prepared in 1980. The conversion factors from daily manual rain gauges read each day at 9 am to maximum 24, 48 and 72 hour rainfall totals were the same as those used by Tomlinson (1980).

The regional frequency analysis this time used more robust techniques following the findings of Pearson and Henderson (1998), and involved the mapping of an index rainfall (the median annual maximum) together with regional frequency distribution growth curves that are assumed to be common to every site within a prescribed region. The mapping of the index rainfall involved fitting a trivariate thin-plate spline to three independent variables longitude, latitude, and site elevation. This type of spline allows for the local variations in terrain to be incorporated into the spline relationships, and a robust fit is achieved by transforming the median annual maximum rainfall before fitting the spline. The regional rainfall frequency growth curves were derived using a GEV distribution combined with parameter estimation by probability weighted moments (equivalent to L moments). The rainfall frequency growth curves depended directly on the GEV parameters – distribution scale parameter a, location parameter u and shape parameter k. Design rainfalls for any site are simply the product of the index rainfall and the regional rainfall growth curve. Version 2 was also a computer based procedure where the user loaded site coordinates into the computer to obtain a table output of design rainfalls.

2.7 THOMPSON 2010 (HIRDS VERSION 3)

Thompson (2010) used 1036 automatic rain gauges with record lengths of at least six years, while the manually read rain gauges totalled 2177. Rainfall sites within 500 m of each other were merged into composite site series allowing for record extension of the high intensity series.

Thompson (2010) followed the methodology of HIRDS version 2 with some refinements. In the regional frequency analysis, a "region of influence" method was used in preference to the use of geographically contiguous regions. In this case, a site-specific "region" was defined by a collection of sites with similar extreme rainfall properties. The homogeneity of selected sites was tested by a method of "test-remove-re-evaluate". Data stratification for contouring of surfaces was based upon three principal meteorological processes, convective, stratiform and a mixture of both, rather than latitude, longitude and altitude. A regional dimensionless growth curve was identified based on the best distribution for each site from the GEV, Gumbel (EV1), and Generalised Logistic (GLO) distributions, using a goodness of fit tests.

Mapping of median annual maximum rainfall and parameters of the regional growth curves, covered New Zealand using thin-plate smoothing ANUSPLIN splines (Hutchinson 1995, 2000), at a 2 km x 2 km grid, and using L moments statistics, resulted in 10 surfaces each representing the 10 durations from 10 minutes to 72 hours, and were extended to a maximum Average Recurrence Interval (ARI) (return period) of 100 years, e.g., Figure 1 shows the median (2-year) annual maximum rainfall surface for a duration of 24 hours. Figure 2 shows the internet front page for HIRDS version 3, and Table 1 provides an example of HIRDS 3 rainfall depth (mm) – duration (minutes or hours) – frequency (years) for the Cropp rain gauge, West Coast, South Island.

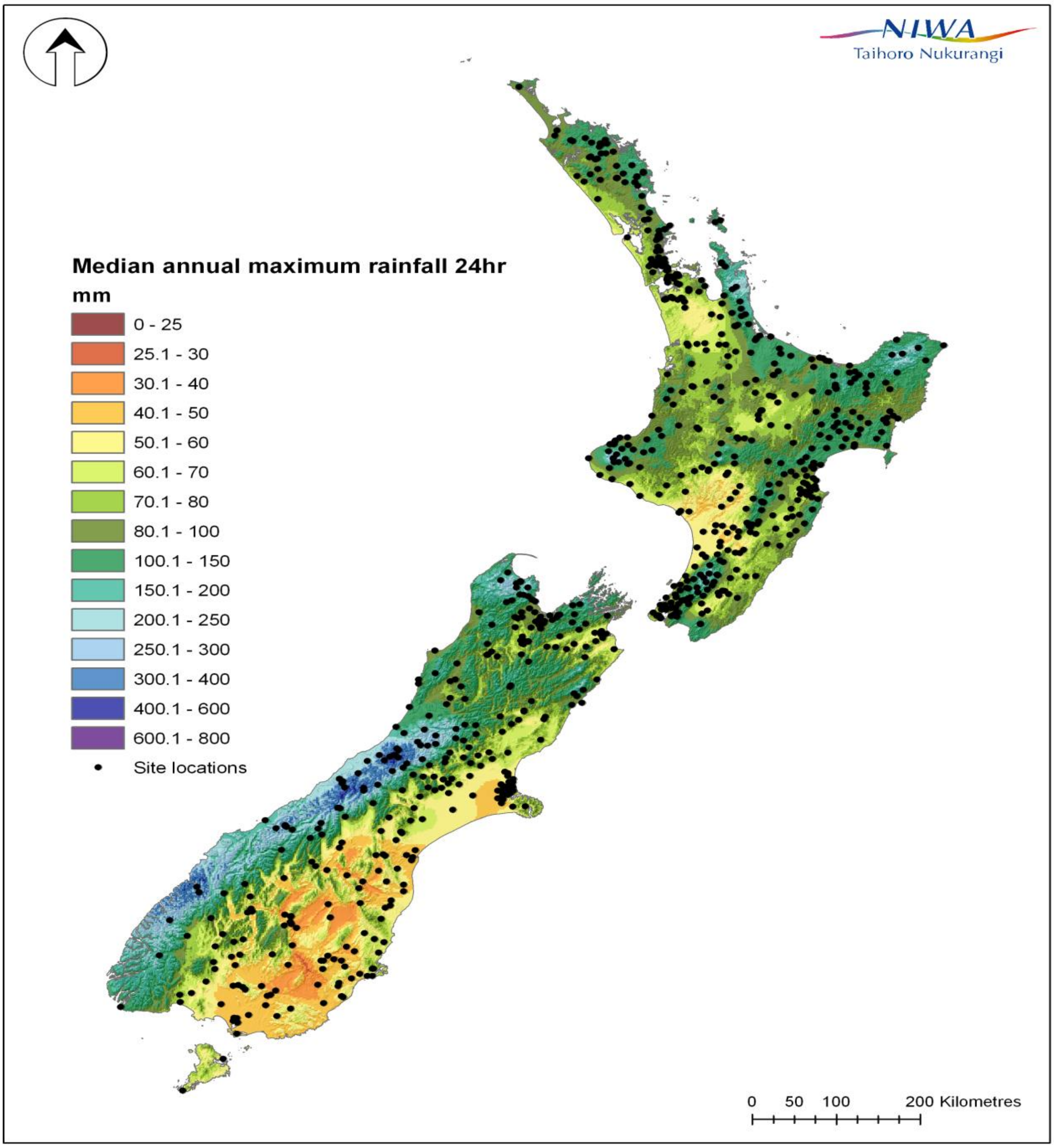

Figure 1: Thompson's (2010) Index-rainfall variable: Median annual maximum rainfall for 24-hour duration.

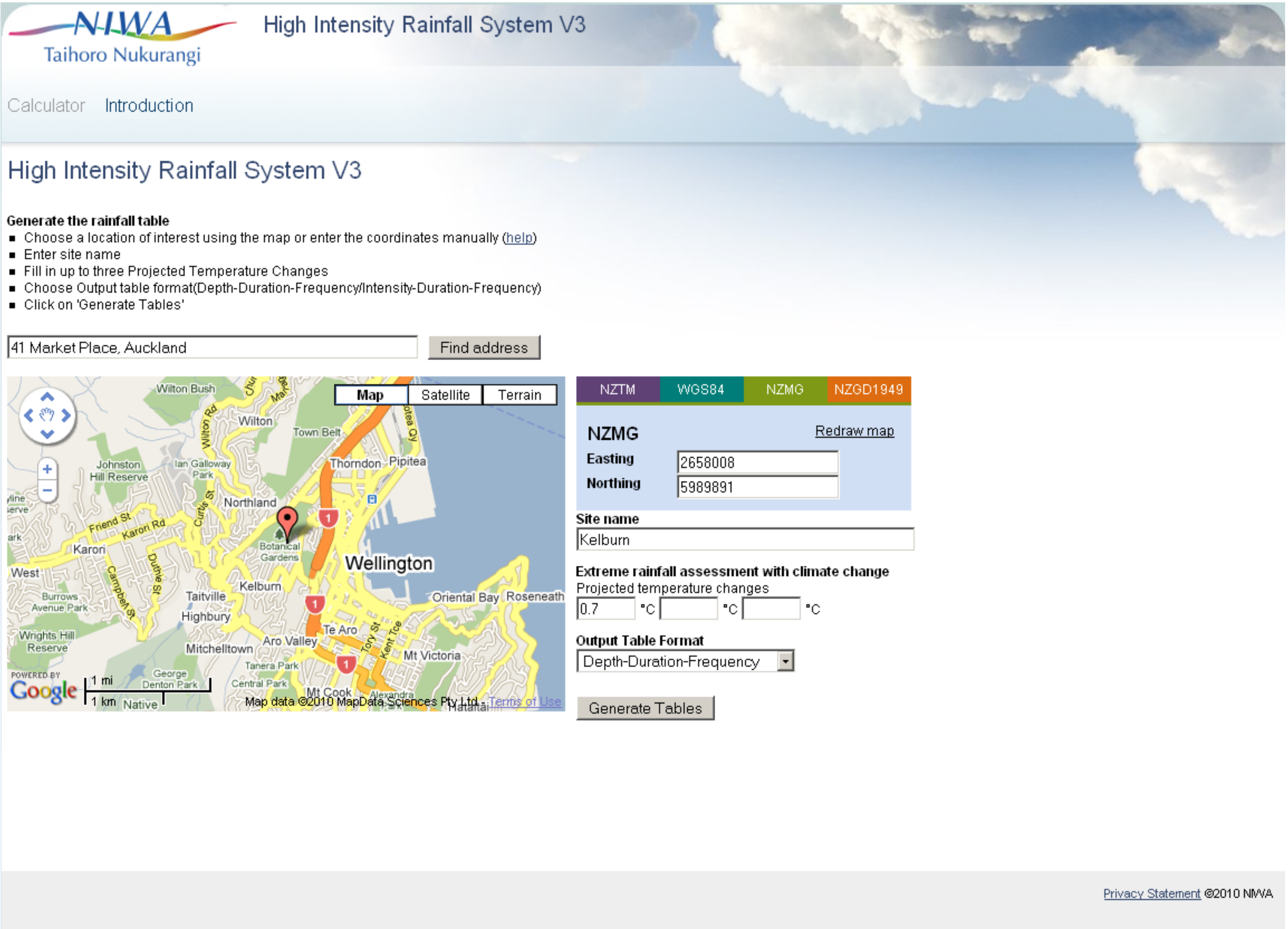

Figure 2: HIRDS version 3 internet page

Table 1: Output taken from HIRDS version 3: (a) rainfall depth (mm) – duration (minutes or hours) – frequency (years) for the Cropp rain gauge, West Coast, South Island (the wettest rain gauge in New Zealand) and (b) standard errors (mm) for the estimates in (a).

(a) Rainfall depth estimates (mm) for durations 10 minutes to 72 hours and return periods from 2 to 100 years.

ARI (y)	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
2	13.6	22.7	30.8	51.6	86.3	195.3	327.0	547.3	727.2	858.6
5	16.9	28.3	38.3	64.2	105.9	233.8	385.3	635.1	843.7	996.3
10	19.5	32.8	44.3	74.3	121.2	263.3	429.6	700.8	931.0	1099.4
20	22.5	37.7	51.0	85.4	138.0	295.1	476.8	770.2	1023.2	1208.2
30	24.3	40.8	55.2	92.6	148.7	315.2	506.2	813.2	1080.4	1275.7
40	25.	43.	58.	98.0	156.	330.	528.	844.	1122.	1325.

	8	2	4		7	1	1	9	5	5
50	26.9	45.1	61.1	102.4	163.2	342.1	545.7	870.3	1156.3	1365.3
60	27.9	46.8	63.3	106.1	168.8	352.3	560.4	891.6	1184.5	1398.7
80	29.5	49.5	66.9	112.2	177.8	368.8	584.5	926.1	1230.4	1452.9
100	30.8	51.7	69.9	117.2	185.1	382.2	603.8	953.8	1267.2	1496.3

(b) Standard errors (mm) for the rainfall depth estimates in (a).

ARI (y)	10 m	20 m	30 m	60m	2h	6h	12h	24h	48h	72h
2	4.3	4.4	4.4	4.4	4.5	5.4	6.6	7.4	8.9	10.6
5	4.4	4.4	4.4	4.6	4.7	6.4	8.3	9.4	11.7	14.1
10	4.4	4.4	4.5	4.9	5.1	7.7	10.5	11.9	15.0	18.3
20	4.4	4.6	4.8	5.5	5.7	9.8	14.0	15.8	20.1	24.6
30	4.5	4.7	5.0	6.2	6.2	11.5	16.7	18.7	23.9	29.3
40	4.5	4.9	5.2	6.7	6.6	12.9	18.9	21.0	27.0	33.1
50	4.6	5.0	5.5	7.3	7.0	14.1	20.8	23.0	29.5	36.3
60	4.7	5.1	5.7	7.8	7.4	15.2	22.4	24.7	31.8	39.0
80	4.8	5.4	6.1	8.7	8.0	16.9	25.1	27.6	35.5	43.6
100	4.9	5.6	6.5	9.4	8.5	18.4	27.4	29.9	38.6	47.4

3 PLANNED UPGRADE

3.1 EXTENSION OF NEW ZEALAND'S RAINFALL DATASET

For HIRDS version 4 it is intended to seek out and include all regional council, city and district Council, MetService and NIWA rain gauges, as well as many other rainfall collectors' information, to compile a complete New Zealand rainfall dataset. An upgrade without all the available data will fail to gain acceptance from end users.

The increased dataset for HIRDS version 4 will improve the overall coverage and extended records of existing stations. This updated dataset will include many known recent storms as well as historic intensity information which was unavailable for version 3.

It is also intended to include a comprehensive list of the rainfall information used in the upgrade for end users to identify data usage.

3.2 VERSION 4 ENHANCEMENTS

Feedback from end users shows there is a need to provide estimates of the average recurrence interval to the 250-year return period, an increase from the previous 100-year return period.

Also, when design engineers estimate design floods from rainfall a catchment rainfall total is required. Version 3 will provide a point rainfall depth for a desired duration and frequency but an areal reduction factor is required for a catchment area. It is intended to complete the first areal reduction curves using New Zealand data, as the curves used frequently in New Zealand are those developed using United Kingdom data (e.g., Faulkner 1999).

When applying rainfall-runoff methods, four design variables are required; rainfall duration derived by the engineer based on catchment characteristics, antecedent catchment wetness selected by the engineer, rainfall depth for a design return period obtained from a HIRDS or an at site analysis, and the storm temporal pattern, which has not been compiled for different regions of New Zealand. A typical 24-hour, hourly temporal pattern as a New Zealand average was provided by Tomlinson (1980), but regional temporal patterns have not been compiled. Therefore whilst HIRDS provides the depth duration frequency rainfall it does not provide the hourly intensities during the storm duration.

The aim of the planned upgrade is the development of a tool to produce rainfall, depth, duration frequency maps for areas, catchments or regions to enable downloads from the web site upon request.

4. CONCLUSIONS / RECOMMENDATIONS

The large increase in available rainfall data (Figure 3) for six studies spanning 63 years has enhanced the accuracy of predictions of high intensity rainfall over New Zealand. The main finding from these studies has been the improvements in the use of frequency distributions, where some locations fit the GEV in preference to the normal EV1 Gumbel distribution.

A vast increase in long term recording rain gauges occurred when regional council data was included in Version 3, making a significant improvement to the rainfall extremes in the foothills and mountainous areas of New Zealand.

Planned upgrades include the compilation of a complete New Zealand rainfall dataset, and estimates up to the average recurrence intervals of the 250-year return period, the development of areal reduction curves, storm temporal patterns and down loadable maps from the web page.

For NIWA to further improve HIRDS, it is recommended that resources are provided to compile all rainfall information in New Zealand. This involves communicating with all organisations collecting rainfall records. This will result in a national database, and will provide the opportunity to carry out 3 yearly updates to HIRDS, to include new rain gauges and extended records of existing records. These improvements would supply hundreds of New Zealand design engineers with the best possible high intensity rainfall and design information.

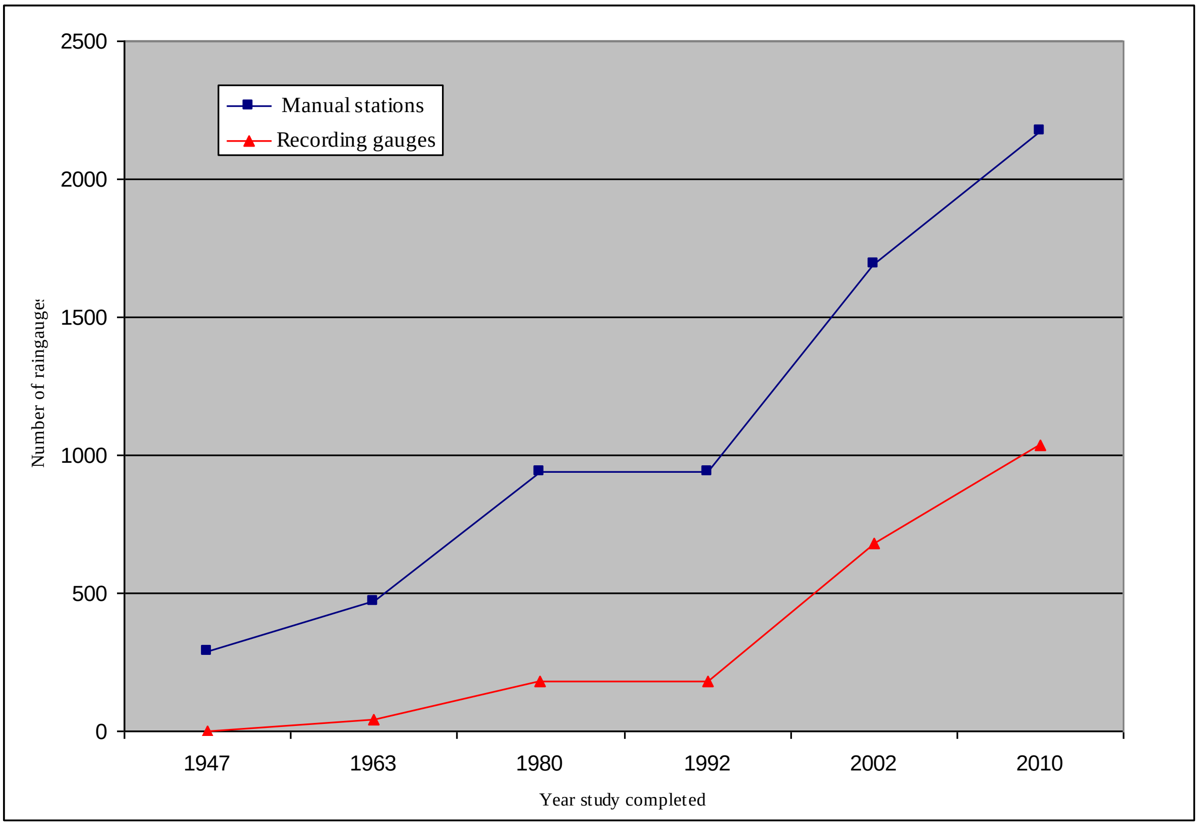

Figure 3: Manual and recording rainfall sites used in studies from 1947 to 2010.

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