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Learning Hydrology by an Australian High School Student

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Abstract

This paper presents the learning experience of a high school student (first author) who was working with an expert hydrologist (third author) for his year 10 industry experience. A student-centred approach was adopted to teach hydrology to the student. In this case study, it was assumed that a bridge was to be designed at the Allyn River, at Halton, New South Wales, Australia (station ID 210022). The task involved abstraction of annual maximum flood (AMF) data from the WaterNSW website and several candidate probability distributions to the AMF data using EasyFit and R software. The ranking of the candidate probability distributions was based on three goodness of fit tests (Kolmogorov Smirnov, Anderson Darling and Chi Squared), which enabled selection of the top five distributions for each test. It was concluded that the Generalised Extreme Value distribution was the best fitting probability distribution for the AMF data at the site. It was found that a student-centred approach can aid in learning hydrology, which is regarded as a difficult subject due to its empirical nature.

Keywords: Engineering education, GEV, flood frequency, high school, hydrology, STEM.

1. INTRODUCTION

Science, Technology, Engineering and Mathematics (STEM) education is a matter of concern at school level in developed countries like Australia. Sharma and Yarlagadda (2018) mentioned that Australia has generally been unsuccessful in engaging adequate number of high-quality school students in STEM education. Goonatilake and Bachnak (2012) proposed several measures to encourage high school students in Texas to be well prepared for up taking STEM education. In December 2015, the Australian state and territory governments endorsed the 'National STEM School Education Strategy 2016-2026', which aimed to improve the STEM capabilities of students nationwide (Murphy et al., 2019). Timms et al. (2018) compared STEM education in Australia to those of other countries and concluded that Australian STEM education is caught in a whirlpool of problems. They stated that student engagement and performance in STEM were at a decline, and the supply of qualified teachers are limited in STEM subjects in Australian high schools.

Tytler (2020) emphasised the importance of STEM education, as it becomes increasingly essential globally. Sahito and Wassan (2024) compiled a range of studies and research papers concerning engagement and popularity of STEM education and deduced that STEM teachers faced many challenges including working conditions, poor funding, lack of job satisfaction and training, which caused many to quit STEM teaching, thus limiting STEM learning opportunities in developed countries worldwide. STEM education is made relevant due to connections between theory and the real world. The large range within STEM allows for different perspectives on the applicability of STEM, even within one high school, showing the importance of STEM education (Xu et al., 2023).

This paper focuses on the engagement of a high school student with an engineering academic as part of the student's work experience in 2024. The perspectives of the student, a high school teacher and a university engineering academic are presented in this paper, which revolves around teaching and learning of a water engineering problem.

2. MATERIALS AND METHODS

The hydrologic problem that is selected in this study is to recommend the design discharge for a bridge, located on the Allyn River, at Halton in New South Wales, Australia. The location of the bridge is defined by 32°21′42.9″S 151°31′55.668″E. It is 89 km north of Newcastle, Australia. The annual maximum flood (AMF) data length at Allyn River is 82 years, from 1941 to 2023. The catchment area covers 203 km^2. The maximum gauge level is 4.317 metres, dated 25th February 1955 as per the WaterNSW website. Halton has an average maximum temperature of 28.3°C and an average minimum temperature of 3.68°C, with annual rainfall of 1151 mm. Halton has a humid, subtropic climate. The picture of Allyn River is shown in Figure 1. Three goodness-of-fit tests were adopted in this study to select the best fit probability distribution for the AMF data for the study site. These are the Kolmogorov Smirnov (K-S) test, Anderson Darling (A-D) test, and the Chi squared (C-S) test.

KOLOMOGORV SMIRNOV (K-S) TEST

The K-S test uses empirical cumulative distribution function (CDF) and theoretical CDF to calculate test statistics. This test can be used to evaluate the level of difference between theoretical continuous distribution being specified and observed distribution from sample data. The K-S test is a nonparametric test and no assumption is required regrading distribution of the sample data. A candidate distribution is needed to run the K-S test. The K-S test statistic (D) is the maximum vertical difference between empirical CDF ($P(X_{\mathrm{n}})$) and theoretical CDF ($F(X_{\mathrm{n}})$) and is expressed as:

$$D = max|P(X\mathrm{n}) - F(X\mathrm{n})| \quad (1)$$

with, $P(X_n)$ is an/the empirical CDF of observed random samples of n ordered observations, and $F(X_n)$ is the theoretical CDF for each of the ordered observations (Sharma et al., 2016).

ANDERSON DARLING (A-D)

The Anderson-Darling (A-D) test is a nonparametric test, which compares expected (theoretical) CDF to an observed CDF. Compared to the K-S test, the A-D test provides higher weight to the tails of distribution. The A-D test statistic (A^2) can be presented by (Solaiman, 2011):

$$A^2 = -n - S \quad (2)$$

where,

$$S = \sum_{k=1}^{n} \frac{2k-1}{n} [\ln F(Y_k) + \ln\{1 - F(Y_{n+1-k})\}] \quad (3)$$

where, n = sample size, $Y_1, Y_2, Y_3 \ldots, Y_n$ are sample data and F = CDF (Solaiman, 2011).

CHI SQUARED TEST (C-S)

The C-S test is a nonparametric test. In this test observed data are grouped into a number of bins (k). Based on the size of sample data, the number of bins can be calculated using an empirical expression where:

$$k = 1 + \log_2 N \tag{4}$$

N is the size of sample. The C-S test statistic is:

$$\chi^2 = \sum_{i=1}^{k} \frac{(O_i - E_i)^2}{E_i} \tag{5}$$

$$E_i = F(x_2) - F(x_1) \tag{6}$$

where, E_i *is* expected frequency for bin i, O_i *is* observed frequency for bin i (Sharma et al., 2016) and x_1, x_2 are the limits for bin i, F is CDF of expected distribution.

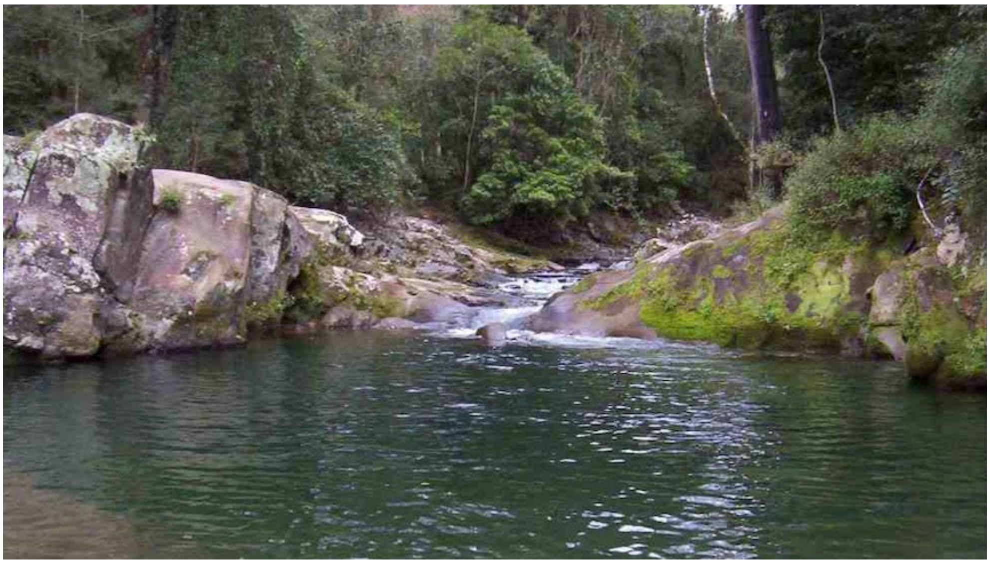

Figure 1. Allyn River (Station ID 210022) (Water NSW, 2024)

3. RESULTS OF FLOOD FREQUENCY ANALYSIS

The top five probability distributions to fit the AMF data at the study site were Generalised Extreme Value (GEV), Weibull, Log-normal, Logistic and Normal distributions. The flood quantiles were estimated for six different return periods (2, 5, 10, 20, 50 and 100 years) as summarised in Table 1. For the 100-year flood Q_{100}, it can be seen that the flood quantile estimate by the log-normal distribution is too high (1203 m^3/s) as compared to the other four distributions. The estimate by the GEV distribution (747 m^3/s) is very close to the non-parametric estimate. Furthermore, the GEV estimated that the Q_{100} value is closer to that of Weibull distribution. The Normal distribution provides the smallest Q_{100} value. Figure 2 compares the Q_T values of the adopted methods. For the proposed bridge design, the Q_{100} value should be taken as 747 m^3/s (GEV estimate). It should be noted that GEV is widely used in flood and rainfall frequency analysis, for example, the design rainfall database (2019) in Australia was developed using GEV distribution.

Table 1. Estimated flood quantiles by different methods

Distribution	Q_2	Q_5	Q_{10}	Q_{20}	Q_{50}	Q_{100}
GEV	162.33	290.60	385.87	485.86	629.10	747.68
Weibull	163.53	303.40	394.58	478.62	582.14	656.16
Log-normal	139.03	303.53	456.51	639.47	934.46	1203.34
Logistic	181.90	291.23	355.19	414.13	488.85	544.32
Normal	195.32	316.22	379.41	431.60	490.34	529.49
Non-parametric	168.6	292.7	374.55	457.85	661.96	689.96

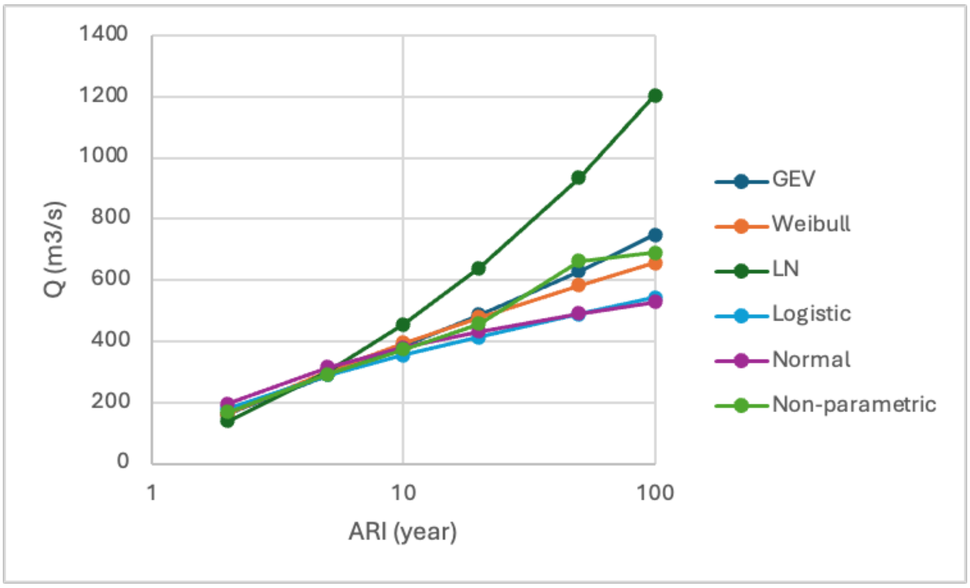

Figure 2. Comparison of different probability distributions and non parametetric-method to estimate flood quantiles at Allyn River at Halton, NSW

4. EDUCATIONAL ASPECTS

Hydrology education is found to be difficult from both the learners' and educators' perspectives as noted by Wagener et al. (2007) as there is a lack of common principles, key knowledge and effective approaches to teach hydrology. A student-centered approach is one of the most effective methods of hydrology teaching as noted by Ngambeki et al. (2012). According to Ruddell and Wagener (2015), the grand challenges in hydrology education in the 21st century revolve around international collaborations among hydrology educators, shared learning tools and formal pedagogies. Van Loon (2019) illustrated how hydrology can be learnt "by doing", where he advocated to use homework-based projects to complement theories taught at class. Rahman et al. (2019) presented how statistical hydrology can be taught effectively using a blended learning approach (a combination of face-to-face and online teaching methods).

Based on the above student-centered approach, the third author of the paper designed a one-week lesson for a high school student who is the first author of this paper. He is a selective high school student of Grade 10 in NSW, Australia. Selective school students are regarded in the top 2% of all NSW students, who are selected based on a competitive examination conducted by the NSW Department of Education. The second author of the paper is a high school teacher who looks at the scientific aspects of this study.

In carrying out the flood frequency analysis exercise stated above, the first author faced several problems: (i) the knowledge gap between the professor and the first author caused discrepancies between what was being said and what was being understood. However, this was overcome by questioning unclear information; (ii) the short period of one week meant that many topics and areas of learning were either skimmed through and skipped, such as learning how to use R software, limiting the first author's understanding of some aspects of learning during this program; (iii) as this was the first time the first author engaged in studying a real-life case study in water engineering, he was unable to complete some tasks without support due to a lack of experience; (iv) the mathematical formulas being used in this investigation (such as GEV distribution) were quite complex, limiting his understanding on the variables in the formula. The new terms that the student learnt included catchment, sample, population, uncertainty, probability, bridge design, goodness of fit test and R.

The third author of the paper found it quite interesting to teach a practical water engineering problem involving statistics to a high school student. The concept of probability was taught to the student via several real-world examples, which was understood by the student reasonably well. The lesson on R programming was enjoyed by the student and the fitting of the GEV distribution to the AMF data by R was easily completed by the student. Overall, the student achieved few important concepts of flood frequency analysis by solving a hydrological problem. It was found that the student had an aptitude for study engineering.

5. CONCLUSION

This study presents the experience of a selective high school student to learn flood frequency analysis. A student-centered approach was adopted to teach hydrology to the student. The student was given the problem, which was solved by reading open-source learning materials in hydrology and asking relevant questions to the educator (the third author of the paper). The concept of probability and simple R programming were introduced to the student. It was found that the NSW selective school student, was able to quickly learn the concept of flood frequency analysis and then solve the given problem. It is noted that the student has developed some appreciation of practical engineering problems, which might positively influence him to pursue engineering in an Australian university. The student may work with a doctoral student for a month during his school holiday and visit hydrology project sites being managed by the hydrology research group at Western Sydney University to enhance and continue his learning in hydrology.

REFERENCES

Brash, B. P., & Rahman, A. (2017). Selection of best fit probability distribution for flood frequency analysis in South West Western Australia. In Proceedings of the 1st International Conference on Water and Environmental Engineering (ICWEE2017), 20-22 November 2017, Sydney, Australia (pp. 108-112).

Goonatilake, R., & Bachnak, R. A. (2012). Promoting engineering education among high school and middle school students. Journal of STEM Education: Innovations and Research, 13(1).

Haddad, K., & Rahman, A. (2016). Estimation of large to extreme floods using a regionalization model. In Landscape Dynamics, Soils and Hydrological Processes in Varied Climates (pp. 279-292). Springer, Cham.

Halgamuge, M. N., & Nirmalathas, A. (2017). Analysis of large flood events: Based on flood data during 1985–2016 in Australia and India. International journal of disaster risk reduction, 24, 1-11.

Hossain, S. M., Rahman, M. M., & Rahman, A. (2017). Queensland flood in 2010-11: will this type of flood occur soon?. In Proceedings of the 1st International Conference on Engineering Research and Practice, 4-5 February 2017, Dhaka, Bangladesh (pp. 102-108).

Murphy, S., MacDonald, A., Danaia, L., & Wang, C. (2019). An analysis of Australian STEM education strategies. Policy Futures in Education, 17(2), 122-139.

Ngambeki, I., Thompson, S. E., Troch, P. A., Sivapalan, M., & Evangelou, D. (2012). Engaging the students of today and preparing the catchment hydrologists of tomorrow: student-centered approaches in hydrology education. Hydrology & Earth System Sciences Discussions, 9(1).

Peden, A. E., Franklin, R. C., Leggat, P., & Aitken, P. (2017). Causal pathways of flood related river drowning deaths in Australia. PLOS Currents Disasters, 1, 1-24.

Rahman, A., Kordrostami, S., Purdy, D. (2019). Statistical hydrology teaching using a blended learning approach, In: Blended Learning in Engineering Education: Recent Developments in Curriculum, Assessment and Practice, CRC Press (Taylor & Francis Group), (eds. Rahman and Ilic), pp. 1-14.

Ruddell, B. L., & Wagener, T. (2015). Grand challenges for hydrology education in the 21st century. Journal of Hydrologic Engineering, 20(1), A4014001.

Sahito, Z., & Wassan, S. H. (2024). Literature Review on STEM Education and Its Awareness among Teachers: An Exploration of Issues and Problems with Their Solutions. SAGE Open, 14(1), 21582440241236242.

Sharma, J., & Yarlagadda, P. K. (2018). Perspectives of 'STEM education and policies' for the development of a skilled workforce in Australia and India. International Journal of Science Education, 40(16), 1999-2022.

Timms, M. J., Moyle, K., Weldon, P. R., & Mitchell, P. (2018). Challenges in STEM learning in Australian schools: Literature and policy review.

Tytler, R. (2020). STEM education for the twenty-first century. Integrated approaches to STEM education: An international perspective, 21-43.

Van Loon, A. F. (2019). Learning by doing: enhancing hydrology lectures with individual fieldwork projects. Journal of Geography in Higher Education, 43(2), 155-180.

Wagener, T., Weiler, M., McGlynn, B., Gooseff, M., Meixner, T., Marshall, L., ... & McHale, M. (2007). Taking the pulse of hydrology education. Hydrological Processes: An International Journal, 21(13), 1789-1792.

Xu, L., Fang, S. C., & Hobbs, L. (2023). The relevance of STEM: A case study of an Australian secondary school as an arena of STEM curriculum innovation and enactment. International Journal of Science and Mathematics Education, 21(2), 667-689.