Journal of Hydrology 549 (2017) 252–263

Contents lists available at ScienceDirect

Journal of Hydrology

journal homepage: www.elsevier.com/locate/jhydrol

Research papers

Evaluating relative merits of four baseflow separation methods in Eastern Australia

Junlong Zhang [a,b], Yongqiang Zhang [b,*], Jinxi Song [a,c], Lei Cheng [b]

[a] College of Urban and Environmental Sciences, Northwest University, Xi'an 710127, China
[b] CSIRO Land and Water, GPO Box 1666, ACTON 2601, Canberra, Australia
[c] State Key Laboratory of Soil Erosion and Dryland Farming on the Loess Plateau, Institute of Soil and Water Conservation, Chinese Academy of Sciences, Yangling 712100, China

ARTICLE INFO

Article history:
Received 16 October 2016
Received in revised form 2 February 2017
Accepted 2 April 2017
Available online 5 April 2017
This manuscript was handled by K. Georgakakos, Editor-in-Chief, with the assistance of Joanna Crowe Curran, Associate Editor

Keywords:
Streamflow
Baseflow separation
Baseflow index
Recession constant
Digital filtering
Catchment
Chemical hydrograph separation

ABSTRACT

Baseflow is the portion of streamflow that comes from shallow and deep subsurface flow, and is the key for catchment ecology and water resource management. This paper comprehensively evaluates four widely used non-tracer baseflow separation methods against tracer-based hydrograph separation for five Eastern Australian catchments. The four methods include United Kingdom Institute of Hydrology (UKIH) method and three digital filtering methods: Lyne–Hollick method, Chapman–Maxwell method and Eckhardt method. The first two filtering methods include a parameter of recession constant, and the last one has two parameters: the recession constant and the maximum baseflow index. We used an Automatic Baseflow Identification Technique (ABIT) to estimate the recession constant, which varies from 0.943 to 0.987 for the five catchments that is evidently higher than the default value of 0.925, and used the default Eckhardt and UKIH methods to estimate the maximum baseflow index, respectively. All modelling results are evaluated against the tracer-based hydrograph separation. Using the recession constant estimated from the ABIT method performs noticeably better than using the default parameter, indicated by the absolute bias reduced about 20% in average. For the two-parameter Eckhardt method, estimating the maximum baseflow index has larger effect on baseflow separation than estimating the recession constant. Compared to the different parameterisation schemes, the difference among the improved non-tracer methods is small. Using multiple passes into the Lyne–Hollick method can only slightly improve or deteriorate baseflow index estimates. Our results suggest that it is critical to get appropriate parameter(s) before applying the digital filtering methods.

© 2017 Elsevier B.V. All rights reserved.

1. Introduction

Baseflow is the portion of streamflow that comes from shallow and deep subsurface flow, and is an important part of the groundwater system (Hall, 1968). It refers generally to groundwater discharge into streamflow (Nathan and McMahon, 1990; Graszkiewicz et al., 2011), and changes gradually over weeks to months (Wittenberg and Sivapalan, 1999). Baseflow component reflects connection to groundwater. All streams respond to rainfall-runoff, but it is the discharge from groundwater that sustains river flow between events. Thus baseflow is important for sustaining aquatic habitats perennially (Fan et al., 2013). Baseflow separation can improve the understanding of catchment streamflow partitioning (Tularam and Ilahee, 2008; Mei and Anagnostou, 2015), and aid water resources management (Arnold et al., 1995), designing flood events by separating flood components (Graszkiewicz et al., 2011; Kinkela and Pearce, 2014), calibration of hydrological models, and deducing aquifer properties and streamflow trend analysis (Tallaksen, 1995; Stewart et al., 2007; Zhang et al., 2014; Lott and Stewart, 2016).

Numerous methods have been developed to separate baseflow from total streamflow (Lyne and Hollick, 1979; Rice and Hornberger, 1998; Spongberg, 2000; Furey and Gupta, 2001; Eckhardt, 2005; Tularam and Ilahee, 2008; Lott and Stewart, 2016). These methods can be divided into two categories: tracer-based and non-tracer-based (Gonzales et al., 2009). The tracer-based methods use chemical and physical means for separating baseflow from streamflow (Gonzales et al., 2009). Natural chemical and hydrogeological tracers are widely used to estimate hydrograph separation (Rice and Hornberger, 1998; Jørgensen and Banoeng-Yakubo, 2001; Uhlenbrook and Hoeg, 2003; Mul et al., 2008; McCallum et al., 2010). The tracer-based methods can provide accurate information between groundwater and surface water with different chemical signatures (Cook et al., 2003;

* Corresponding author at: CSIRO Land and Water, Clunies Ross Street, Canberra 2601, Australia.
E-mail address: yongqiang.zhang@csiro.au (Y. Zhang).

http://dx.doi.org/10.1016/j.jhydrol.2017.04.004
0022-1694/© 2017 Elsevier B.V. All rights reserved.

McCallum et al., 2010; Klaus and McDonnell, 2013; Lott and Stewart, 2016), and therefore can be taken as reference to assess the non-tracer baseflow separation methods. A typical example is an environmental isotope that can be used to calculate transit time for the water storage in the catchment (Kirchner et al., 2000; McGuire and McDonnell, 2006). Heat is another tracer used to determine the interactions between groundwater and surface water (Anibas et al., 2011). Chemical tracers including ^{2}H, ^{18}O, silica and chloride have been used in hydrograph separation (SKM and CSIRO, 2012). In addition, electrical conductivity is an important and robust hydrogeological tracer applied to estimate groundwater inflow (Moore et al., 2008; Pellerin et al., 2008). The major disadvantage of tracer-based methods is that they are very time-consuming, requiring a long time to collect samples and conduct analyses. Therefore, it is difficult to apply this method widely or for large numbers of catchments.

To overcome the disadvantage of the tracer-based methods, various non-tracer based methods were developed over past several decades. Digital filtering is the major category of the non-tracer based methods (Eckhardt, 2005). A widely used digital filtering method is the Lyne–Hollick method (Lyne and Hollick, 1979). It splits streamflow into quick flow and baseflow using one parameter (recession constant). Based on this method, several automated techniques were developed for baseflow and recession analysis in Australia (Nathan and McMahon, 1990; Chapman, 1991). The Lyne–Hollick method is not recommended for ephemeral streams because the hydrographs are characterised by short fast responses and lack a sustained slow flow component (Eckhardt, 2005). Chapman (1991) developed an algorithm that can be used for separating baseflow from streamflow for ephemeral rivers. Eckhardt (2005) proposed a two–parameter (maximum baseflow index and recession constant) recursive digital filter (RDF) for baseflow separation, a good approximation for baseflow sequences with manual separation techniques such as matching strips (Toebes and Strang, 1964; Aksoy and Wittenberg, 2015). Some other non-tracer methods reported in literature include graphical and statistical methods and the United Kingdom Institute of Hydrology (UKIH) method. The graphical and statistical methods are based on the assumption that discharge from an aquifer varies linearly (Hall, 1968). The UKIH method is widely used since it is easy to apply and it calculates the baseflow through identification and interpolation of turning points based on daily streamflow data (Gustard et al., 1992; Piggott et al., 2005).

Recession analysis is used to extract recession of the streamflow using catchment characteristics (Knisel, 1963; Tallaksen, 1995). There are various methods used for the recession analysis, including graphical approaches (Hall, 1968; Collischonn and Fan, 2013), power-law relationship (Krakauer and Temimi, 2011), and empirical function (Kirchner, 2009). However, these methods are lack of physical meanings and sensitive to the start point of baseflow separation. Furthermore, it is impractical to use these methods to define new time origin for a long term streamflow recession (Zhang et al., 2014), and it is hard to guarantee their separation quality (Stewart, 2015; Su et al., 2016). Cheng et al. (2016) developed an Automatic Baseflow Identification Technique (ABIT) for the recession analysis. The major advantage of this method is objective and physically meaningful since it can capture characteristics of multiple recessions that cannot be detected by analyzing individual recessions (Brutsaert, 2005). Therefore, this study utilises the ABIT for quantifying the recession constant and checks its merits for improving baseflow separation. Details for ABIT are introduced in section of Data and methodology.

The main aim of this study is to evaluate the relative merits of four non-tracer baseflow separation methods, including UKIH and three digital filtering methods (Lyne–Hollick, Chapman-Maxwell and Eckhardt) against the chemical hydrograph method for five Eastern Australian catchments (Fig. 1). The specific objectives include: (1) investigating different parameterisation schemes for recession constant and the maximum baseflow index, (2) evaluating relative merits of the four non-tracer methods, and (3) evaluating the benefit of increasing the number of passes from one to ten.

2. Data and methodology

2.1. Study area and data

This study chose five catchments with available chemical observations for baseflow separation. These catchments are located in Eastern Australia (Fig. 1), where a chemical hydrograph method was used for the baseflow separation studies (SKM and CSIRO, 2012). The detailed information of the five catchments is summarised in Table 1. All the catchments have gaining rivers with small to medium volumes of streamflow, and have a wide range of geological, land use and climatic conditions.

Cattle Creek is a perennial stream in semi-arid to warm dry monsoonal area. It has clayey black soils, volcanic structural benches and limestones (Strong et al., 1986).

The Nambucca River catchment has fine subtropical climate, covered by rainforest and with high rainfall. Its geology is Permian metasediments consisting of slate and sandstone (McCallum et al., 2012).

Ourimbah Creek is a mostly perennial stream. The soil in this catchment is dominant by buried sediments and sandstones (Loughnan et al., 1964). Its vegetation is mainly the rainforest (Letcher et al., 2004).

Tarcutta Creek is located in the western foothills of Australia's southeaster highlands, which is mostly a perennial stream, and the erosional and depositional substance are distributed in this region. The vegetation is predominated by the high trees (Page and Carden, 1998).

Cockburn River is one of the intermittent rivers (Cook et al., 2006). The geology consists of Carboniferous metasediments and alluvial sediment (McCallum et al., 2012).

The daily observed streamflow data for Cattle Creek catchment were obtained from the Water Monitoring Information Portal of Queensland Government (2016), and for the other four obtained from the NSW Office of Water (2016). Streamflow data length used for this study for the five catchments ranges from 7 to 32 years, summarised in Table 1.

The Baseflow Index (BFI) is defined as the proportion of streamflow that is baseflow over a long period of streamflow record (one year or entire observation period) (Gustard et al., 1992; Smakhtin, 2001; Beck et al., 2013). The BFI of the five catchments, calculated from the chemical hydrograph separation of two years (2008–2009) of experimental observations reported in SKM and CSIRO (2012), were used for validating the non-tracer methods investigated here.

The field observations for each catchment were collected over 2008 and 2009 at a two-week interval. They were conducted along 20–30 km river reaches where a streamflow gauging station was sited. Three chemical tracers were measured including electrical conductivity, chloride concentration and radon activity. The BFI obtained using the chemical hydrograph separation for the two year records varied from 0.27 for Cattle Creek and Cockburn to 0.42 for Ourimbah (Table 1).

2.2. Non-tracer baseflow separation methods

Four non-tracer baseflow separation methods were compared: UKIH and three digital filtering methods including Lyne–Hollick (LH), Chapman–Maxwell (CM), and Eckhardt (ECK) filters.

Download English Version:

https://daneshyari.com/en/article/5770981

Download Persian Version:

https://daneshyari.com/article/5770981

Daneshyari.com