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IRRISOFT Siphon - A simple on-line irrigation tool for computing the discharge of siphons

IRRISOFT Siphon - Eine einfache online Bewässerungsanwendung zur Berechnung der Durchflussleistung von Hebern

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Stichworte
Heber, Bewässerungsentwurf, Bewässerungsmanagement, online Anwendung, Software
Keywords
Siphon, irrigation design, irrigation management, on-line application, software

Abstract
One of the key issues when designing or managing a surface irrigation system where siphons are to be used is how to select the most appropriate type, dimension and number of siphons and what should the head be to achieve the desired flow. The normal procedure would be to either use some more general or specific flow tables and charts or to apply the more laborious direct computational method. IRRISOFT Siphon is a free and easy to use on-line irrigation tool which allows to compute the discharge of one or a self defined number of siphons easily adjustable for various field conditions. It was designed with the main objective to assist e.g. irrigators and extension staff in getting a first but reasonable accurate estimate when trying to find the optimal siphon setup. A brief introduction is given into the background, the computational process as well as its limitations. An practical example run with in- and output values of this on-line software application is also included.

Zusammenfassung
Für den praktischen Einsatz von Hebern bei der Stau- und Rieselbewässerung sind Fragestellung bezüglich der Art, Dimensionierung und Anzahl der Heber zur optimalen Auslegung und des späteren Managements wichtig um z.B. die gewünschte Durchflussleistung bei gegebener Druckhöhe zu erhalten. Der Entwurf erfolgt häufig unter Verwendung von verallgemeinernden oder spezifischen Tabellen und Nomogrammen oder direkt über die Berechnung unter Benutzung arbeitsintensiver Rechenwege. IRRISOFT Siphon ist eine frei zugängliche und einfach zu bedienende online Anwendung, die den Durchfluss von einem oder einer selbst bestimmten Anzahl von Hebern berechnet. Die Anwendung läßt sich einfach an unterschiedliche Feldbedingungen anpassen. Ziel dieser Anwendung ist es z.B. dem Bewässerungslandwirt oder Berater ein Hilfsmittel an die Hand zu geben, welches ihm die Ermittlung einer angemessen und genauen Planungsgröße für einen optimalen Einsatz von Hebern bei der Bewässerung erlaubt. In dem nachfolgenden Artikel werden kurz die Hintergründe beschrieben, die Berechnung erläutert und die Grenzen der Anwendbarkeit diskutiert. Außerdem wird an einem Fallbeispiel eine Berechnung mit Ein- und Ausgabewerten dieser online Anwendung dargestellt.

1. Introduction

A siphon is defined as a "closed conduit (duct) with a part rising above the hydraulic grade line. As this upper part is subjected to subatmospheric pressure, the siphon must first be primed by exhausting air from it" (ICID-CIID, 2000). Siphon tubes are curved pipes which are laid over the bank of a delivery channel as shown in Figure 1. Siphons are made e.g. from PVC or aluminium and are a cheep and efficient way to transfer water from channels into furrows or bays for irrigation. This is especially the case where flexibility is needed or erodable earthen channels are used which could cause outlet pipes or bay gates to be washed out. While the process of starting the siphons is labour intensive it is still possible to start more than 100 siphons an hour. The necessary flow per furrow, set of furrows or bays may easily be adjusted by using several siphons feeding into the same furrow or bay. Siphons exist in a variety of sizes generally ranging from 13 to 150 mm in diameter and 1.2 to 3.0 m in length. However many different sizes and dimensions exists from which many are custom made such as large metal siphons with diameters of more than 800 mm and some 18 m length. Smaller siphons may be primed manually. Larger ones need more preparations and need to be primed by a vacuum pump.

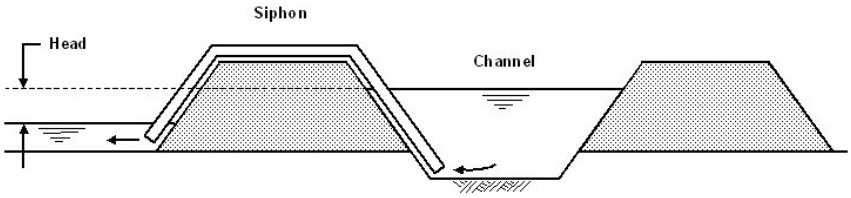

Figure 1:
Siphon - Schematic layout of a siphon system on an irrigation channel. The hydrostatic head acting on a siphon is indicated as the height difference between water level in the channel and the water level in the field

One of the key issues when designing or managing a surface irrigation system where siphons are to be used is how to select the most appropriate type, dimension and number of siphons and what should the head be to achieve the desired flow. The head often varies due to water level changes in the channel as irrigation proceeds with significant impact on the flows through the siphons. The normal procedure would be to either use some more general or specific flow tables and charts provided in some irrigation design manuals (e.g. ARC-ILI, 2003) and by extension or research services (e.g. WIGGINGTON, 2004) or by applying the more laborious computational methods as described e.g. by BOS (1989) or HORTON and JOBLING (1984). Alternatively and far less error proned is the use of small software tools

which would allow to easily juggle with the various often changing input values. Many tools are programmed and designed for the use on personal computers. However, alternatively on-line applications may be used which run on an Internet server and where only a standard Web browser is needed (which are part of every operating system) to make full use of the software functionality. The use of such on-line applications avoid all installation and update procedures and keeps the computer free of unwanted software which may remain as a trial and error result. In addition it is independent from the locally used operating system as nothing is being installed on the user's machine. Consequently it runs with all operating systems such as Microsoft Windows, Mac OS, Linux, etc. IRRISOFT Siphon is such an on-line irrigation tool which allows to compute the discharge of one or a self defined number of siphons easily adjustable for various field conditions. It is the first tool of its kind released free of charge through the IRRISOFT (STEIN, 1996) services on the Sakia.org site.

2. Programming and background

2.1 Software used for programming

IRRISOFT Siphon is a server based application and it consist of more than 1000 lines of code. It was programmed in the widely used general-purpose scripting language PHP. PHP is an open source product which is freely available for many platforms. It is especially suited for Web developments as it may be embedded into HTML. In addition numerous options exist such as database linkages and various libraries for various applications. For the dynamically created graphical output PHPLOT was used. It is an open source graphical library written in PHP and based on the GD library for the dynamic creation of images.

2.2 Computational background

The formula used to compute the discharge from siphons is based on HORTON and JOBLING (1984) as shown below

$$Q = 10^{-5}\sqrt{\frac{1.24gHD^5}{0.00015D + \frac{124n^2L}{D^{\frac{1}{3}}}}}$$

where

Q	=	Discharge (l/s)
g	=	Acceleration due to gravity (9.8 m/s²)
H	=	Head (m)
D	=	Actual internal diameter (mm)
n	=	Manning's roughness coefficient
L	=	Length (m).

Additional values for Manning's roughness coefficient (n) were derived and collated from lists published by ACHTNICH (1980), ARC-ILI (2003), BARFUSS and TULLIS (1994), ISRAELSEN and HANSEN (1962) and METCALF and EDDY (1981). This formula has been widely used in the past especially in the Australian context. However, WIGGINGTON (2004) suggests the use of the more accurate equation proposed by BOS (1989) which describes the theoretical flow through siphons as shown below

$$Q = \frac{\pi D^2}{4}\left(\frac{2g\Delta H}{1.9 + f\frac{L}{D}}\right)^{0.5}$$

where

Q	=	Discharge (m^3/s)
g	=	Acceleration due to gravity (9.8 m/s^2)
H	=	Head (m)
D	=	Actual internal diameter (m)
f	=	Friction loss coefficient of Darcy Weisbach (0.019 e.g. for "small diameter pipes")
L	=	Length (m)

Please refer to original references for additional information, conditions and limits of application!

A comparison of the flow differences between the two formulas is given in Figure 2 as a percentage deviation of discharge of 'Horton-Jobbling (Mannings)' from the 'Bos ' equation. Discharge deviations are given in percentage for siphons of various diameters (22 - 250 mm) and lengths (1.5, 2.0, 3.0, 4.0 and 6.0 m) for smooth pipes (e.g. PVC). Assuming a higher accuracy of the 'Bos' equation the used 'Horton-Jobbling' equations seems to underestimate especially flows from small diameter siphons of shorter length whereas flows from larger diameter and longer siphons seem to be moderately overestimated. However, depending on the diameter and length combinations of the siphons in use both formulas may compute very similar flows. The 'Horton-Jobbling (Mannings)' formula was used as it provides most flexibility and enough accuracy for most practical conditions.

2.3 Application conditions and error reduction

IRRISOFT Siphon is being provided with the main objective to assist irrigators and extension staff in getting a first but reasonable accurate estimate when trying to find the optimal combination of number and sizes of siphons for various heads to achieve a desired flow. It is easy and quick to juggle around with the various parameters which would normally be a more laborious, time consuming and error-proned task. Even using traditional charts may easily result in errors in discharge readings in the

range of 10% and more. Like for most systems it is highly recommended to compare computational results with field values and then to adjust accordingly. However, this programme is not meant to be suitable for research purposes where higher accuracy may be needed.

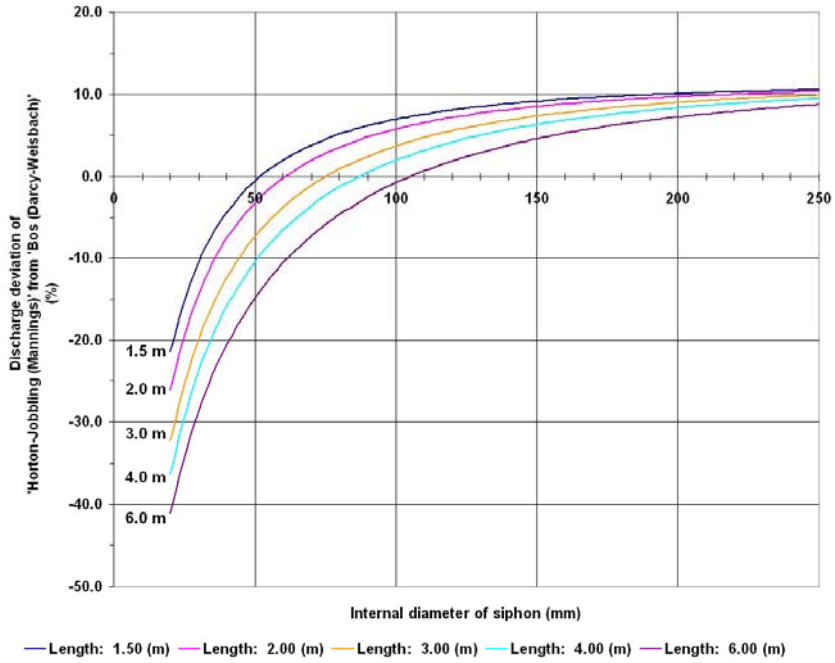

Figure 2:
Discharge deviation (%) of the 'Horton-Jobbling' from the 'Bos' equation for smooth siphons (PVC) of various diameters (22 - 250 mm) and lengths (1.5, 2.0, 3.0, 4.0 and 6.0 m)

To reduce errors to a minimum it is very important to enter exact values in relation to the siphons used as well as to find the exact head of operation. The head often varies as irrigation proceeds with significant impact on the flows. A incorrect estimate of the head in the magnitude of 10 cm may already lead to approximately 10% of flow difference. Variation in heads may especially occur when siphon irrigation starts and new siphons are primed along the channel or when the channel inflow does not match the total outflow through the siphons in use causing a drop or rise in water levels. Another error may occur when the siphon initially runs free and then head changes take place when the outlet gets submerged through the backwater in the furrow or bay. BOS (1989), recommends the use of a transparent hose acting as a

siphon to determine the exact operational head in the field (Figure 3). The head is measured as the height difference between the water level in the channel and the water level in the field when the siphon outflow is submerged, or between the water level in the channel and the centre of the siphon outlet when the siphon outlets flows freely.

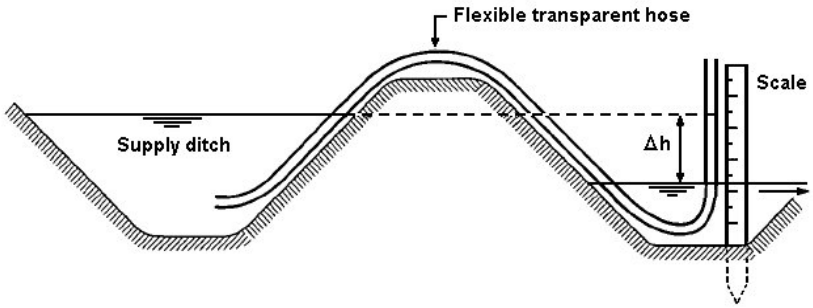

Figure 3:
Simple and accurate head measurement for siphon irrigation by using a flexible transparent hose and scale (Source: BOS, 1989)

3. IRRISOFT Siphon - how to use the on-line application

3.1 Introduction and access to the application

The usage of IRRISOFT Siphon is intended to be straight forward and easy with no prior knowledge needed. The on-line application is accessible through the following address at the Sakia.org site and its usage is provided free of charge.

http://www.sakia.org/irrisoft_siphon

3.2 Software inputs

Performing the input is fast as some example and default values are already filled into the input fields allowing quick familiarisation with the application. Other assistance is given by providing predefined values to be selected in a drop down box. All the input values are being checked for their correctness. Errors are being displayed beside the false entry and hints are given on the type of value to be entered. In addition a more detailed pop-up help system is implemented and is accessible through the "?" link. It is allowing to seek assistance through a little pop-up help window without leaving the main application.

During an input process only a maximum of five values are required to be entered or selected. These values will stay in the memory of the input fields for the next run of the same session. Therefore, to evaluate different conditions such as hydrostatic head or number of siphons only the value of interest needs to be adjusted for the next run. The input parameters are as shown in Table 1 displaying the default and example values, the units as well as a short explanation.

Table 1:
Input parameters for IRRISOFT Siphon including default example values which are found when accessing the application on-line as well as the units and a short explanation

Item description	Value	Unit	Description
Number of siphons in use:	1	(#)	The Number of siphons for which the discharge shall be computed. Any positive integer may be entered here. The graphical output will only display the discharge of one siphon.
Head:	0.5	(m)	The Hydrostatic head is the height difference between water level in the channel and the water level in the field. This is applicable if the siphon outlet is submerged (see Figure 1). However if the outlet flows freely the head is the height difference between channel water level and the centre of the siphon outlet end.
Internal diameter:	18.4	(mm)	The actual internal diameter of the siphon.
Length:	2.0	(m)	Total overall length of the siphon (when stretched out).
Roughness coefficient:	0.01	(PVC)	The roughness coefficient is a number describing the roughness of the material. The discharge is reduced when the roughness increases. Different materials may be selected from the dropdown box (e.g. PVC, steel, concrete and PE corrugated type, etc.)

3.2 Software outputs

The results of the discharge computation for an example run (Table 2) are summarised in a discharge table (Table 3) giving the values for a single as well as for the total number of siphons. In addition a graphical plot of discharge versus head is dynamically created for one siphon as shown for an example in Figure 4. In this way it is easy to compute the discharge to be applied for a furrow, bay or for the entire field for different types of siphons and under different head conditions. Hence the total flow required in the field channel may easily be determined. The results are being displayed in different units allowing the user to pick the units most appropriate for the magnitude of flow or most familiar or widely used (l/s, l/min, m^3/h, ML/day).

As an example the discharge for one and for thirty siphons was computed. The respective input values are shown in Table 2. The results are given in Table 3 for one and for thirty siphons with a graphical output of discharge versus head for one siphon in Figure 4.

Table 2:
Input values and settings for an example run

Item description	Value	Unit
Number of siphons in use:	30	(#)
Head:	0.3	(m)
Internal diameter:	18.4	(mm)
Length:	3.0	(m)
Roughness coefficient:	0.01	(for PVC)

Table 3:
Example output table for discharge based on the input values of Table 2 for one as well as for 30 siphons

Discharge	Discharge	Unit
- 1 siphon (1x)	- 30 siphons (30 x)	
0.214	6.412	(l/s)
12.823	384.691	(l/min)
0.769	23.081	(m^3/h)
0.018	0.554	(ML/day)

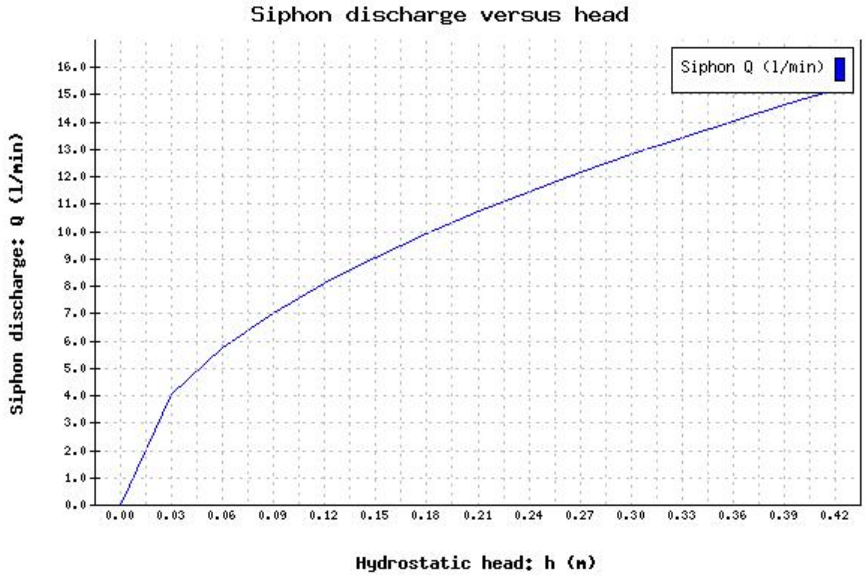

Figure 4:
Screenshot of discharge versus head plot for one siphon with an internal diameter of 18.4 mm, a length of 3 m and a roughness coefficient of 0.01 for PVC as to the example values of Table 2

4. Some future perspectives of IRRISOFT at Sakia.org

The original IRRISOFT was/is an on-line Irrigation and Hydrology Software Database established in 1995 at the Department of Rural Engineering and Natural Resource Protection of the University of Kassel in Germany. It was meant to aid users in finding the right software application for their needs (STEIN, 1996).

The new IRRISOFT server and services are intended to extend the traditional database on software descriptions (inventory) by providing additional functionality in the range of dedicated on-line applications. The majority of applications in the field of irrigation, drainage and hydrology have been written as stand-alone versions to be run on local workstations and PCs. Improved and extended on-line versions are much more effective in reaching a wider audience of users as well as allowing a far extended functionality and linkage of data. Integrated packages are to be developed allowing one application to cover a wider spectrum such as crop water use, irrigation scheduling, climate predictions, growth models, etc. Customised logins will allow users to store previous sessions as well as personalised data on crops, soils, etc. The

new IRRISOFT provides the framework for a new generation of on-line applications thematically placed within the 'land and water' arena.

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PHPLOT, Open source graph library for dynamic scientific, business, and stock-market charts. Written in PHP and based on the GD Library. http://sourceforge.net/projects/phplot/

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Websites

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