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Research Article

Designing an Efficient Appurtenance for Open-Channel Flows in Combined Sewer Systems

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Abstract: An efficient sewer appurtenance for open-channel flows, applied in combined sewer systems, is presented. The facility has been successfully applied in several parts of the combined sewer system of the city of Patras (Greece) achieving combined sewage-rainwater bypass during (and soon after) storm events, where rainwater and sewage–as a mixture-flow together in a common pipe. The appurtenance ensures: a) the complete collection of the sewage flow during dry periods and its diversion to the main sewage collector pipe that concludes to the Wastewater Treatment Plant (WWTP) of the city, and b) partial drainage of the sewerage flow mixture (i.e., rainwater and sewage) to the sea (i.e., the terminal water receptor) during (and soon after) rainfall events, as a means of minimizing the excess hydraulic supply ending to the WWTP, thus maintaining its design capacity regardless the rainwater discharge conveyed by the combined sewer system. In this preliminary study, basic design characteristics of the proposed appurtenance, called diversion manhole, are given. Two different approaches to construct a diversion manhole are presented, and basic design characteristics are discussed. In the context of preliminary design hydraulic considerations, by applying basic hydraulics, it is shown that each of the proposed approaches has significant effect on the reduction of the discharge of the sewage and stormwater mixture conveyed to the WWTP during (and soon after) rainfall events.

***Keywords*:** sewerage, diversion manhole, stormwater, free-surface flow, open-channel flow

Nomenclature

Symbol	Description	Unit
D	Diameter of the combined sewer pipe, or diameter of the overflow drainage pipe of the mixture	m
d	Diameter of sewage connection-pipe	m
D_h	Hydraulic drop (between the combined sewer pipe and the overflow drainage pipe)	m
H_r	Total hydraulic head (pressurized flow)	m
H_s	Total hydraulic head (free-surface flow)	m
$i_s = H_s/L_a$	Slope of the energy grade line (dry periods, sewage flow)	-

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$i_r = H_r/L_a$	Slope of the energy grade line (storm events, flow of sewage and stormwater)	-
L_a	Length of the sewage connection-pipe between the two manholes	m
L_w	Length of the weir overflow crest	m
n	Manning's roughness coefficient	$m^{-1/3}s$
Q_r	Discharge of sewage connection-pipe (pressurized flow)	m^3/s
Q_s	Discharge of the sewage connection-pipe (free-surface flow)	m^3/s
y	Thickness of the overflow vein of the weir	m

1. Introduction

An urban area requires careful hydraulic design, in order to provide adequate and safe sewage as well as stormwater disposal. In sewerage systems a distinction is made between sanitary sewer systems-designed to carry solely domestic sewage and industrial waste-and storm sewer systems-designed to carry solely stormwater, which includes surface runoff and street wash. The distinct presence of the previous two systems in a city constitutes the separate sewer system, where stormwater is carried separately from domestic and industrial wastes.

Contrary to separate sewer systems, a combined sewer system is designed to carry domestic sewage, industrial waste and stormwater in a common pipe. While modern practice demands separate sewer systems, the combined sewer system remains as the basic sewerage system for many cities in the world and especially in their central regions. Combined sewer systems suffer from significant flows or excessive discharges, resulting primarily during and soon after storm events. The mixture of rainwater and sewage is characterized by high discharge values that are close, or even exceed, the design capacity of the Wastewater Treatment Plant (WWTP), where the combined sewer system concludes. More specifically, during dry periods, the effluent discharge conveyed to the WWTP is characterized by low (high) hydraulic (environmental) loads, where the opposite occurs during (and soon after) storm events.

Sewer systems comprise numerous devices in order to ensure proper operation and regulation of the flow, especially during storm events when the sewerage flow mixture (i.e., rainwater and sewage) attains high discharge values. In order for sewer surveillance and accessibility to be ensured, a variety of appurtenances has been developed by technical/engineering practice, including manholes, inlets, retaining basins, inverted siphons, pumping stations and regulators; see [1]. In combined sewer systems, diversion devices are commonly used to limit the flow reaching the WWTP, including side-overflow weirs, leaping weirs (see [2]) and sideweirs ([3], [4]).

Regarding the aforementioned appurtenances applied to sewerage systems, numerical simulations as well as experimental studies have been carried out by many researchers in recent decades. Marsalek [5] experimentally studied the head losses at sewer junction manholes taking into account the junction geometry. Based on this study, the head losses inflow-through junctions were found to be proportional to the velocity head. Moreover, the head loss coefficient in wide junctions with or without benching was also studied. Del Giudice and Gissoni [6] experimentally studied the main hydraulic features of vortex drop shafts as well as examples of their missdesign and consequent malfunction. Based on this study, technical solutions to enhance these vortex shafts using a supercritical flow approach were identified. Pfister and Gisonni [7] conducted an experimental campaign to investigate the local head losses at junction manholes with various conduit diameters under sub- and supercritical approaching flows. Their experimental results along with the application of the basic principles of mass, energy and momentum conservation provided theoretical expressions for the head loss coefficients, which are in good correspondence with the measurements made. In order to apply a standard vortex drop shaft, Pfister et al. [8] proposed a novel concept that comprises a junction chamber to merge the inflow branches followed by a very short and steep inlet channel. The feasibility of their concept has been validated via preliminary numerical simulations and extended via physical model tests. Helmi et al. [9] used the Flow-3D Software package for the 3D simulation of the flow in rectangular stacked drop manholes, in order to assess the impact of the geometric configuration and flow conditions on the energy dissipation efficiency. Based on the conducted numerical simulations, interesting conclusions were drawn regarding the geometric characteristics, as well as the hydraulic energy dissipation efficiency of the corresponding appurtenance.

In the context of best management practices, devices that function as flow splitters can be used to regulate the flow

of the sewerage flow mixture in combined sewer systems. During dry periods, these facilities divert the sewage flow to the sewage network to be transported to the WWTP and, during (and soon after) storm events, bypass the discharge of the sewerage flow mixture in excess of the design capacity of the sewage network to the sea (i.e., the terminal water receptor). As a general rule, a critical factor in the design of flow splitters is to ensure that, during dry periods, the maximum flowrate of sewage dictated by the water quality study is delivered to the treatment plant. In the case of high flow conditions (i.e., during and soon after storm events) when this rate is exceeded, the excess flow remains either in the storm drain or it is diverted to the nearest terminal water receptor (e.g., the sea, a detention pond or a receiving stream) through a bypass drain. Crucial design criteria as well as design guidance for flow splitters can be found in [10] and [11], respectively.

The practice of flow splitters seems to have been adopted in [12]. Indeed, most Ontario municipalities do not permit the application of mechanical/electrical controls on stormwater management facilities, as a means of avoiding operational and maintenance problems associated with the existence and simultaneous operation of numerous real-time control systems under their jurisdiction. Instead, it is more preferable the design of flow splitter's function to be based on hydraulic principles.

The development of the previously mentioned appurtenances as well as the relevant research of the last decades reveal a continuous effort to ensure maintenance, monitoring and good operation of urban sewer systems. The problem of excess-flow diversion remains alive mainly at the central parts of many European cities, where combined sewer systems are kept in operation. The application of the previously discussed flow diversion systems aims at reducing the sewage and stormwater mixture discharge transported to WWTPs through the main sewage collector after storm events, leading to increased operational costs and possible malfunctions.

In this paper, a technical solution is presented, in order to divert part of the sewerage flow mixture (i.e., stormwater and sewage) resulting during (and soon after) storm events to the nearest terminal water receptor. Ultimate scope is to attain the design hydraulic capacity and treatment capability of the receiving WWTP during storm events, when high flowrates are observed. The presented design approaches have been extensively used by the Municipal Enterprise of Water Supply and Sewerage of Patras (DEYAP) to construct a type of flow splitter known as diversion manhole in the central region of the city, based on previous experience of malfunctions detected in older constructions.

2. Method

2.1 *The basic idea of the diversion manhole*

During and soon after storm events, the discharge rates of the sewerage flow mixture (i.e., storm water and sewage) attained in the pipes of the combined sewer system, render their direct connection to the main sewage collector pipe unfeasible. The reason for this is that, during and soon after storm events, the combined sewer system carries a significant amount of stormwater with flowrates that exceed the hydraulic capacity and treatment capability of the receiving WWTP. In fact, this is the case even for light rainfall characterized by low intensity and prolonged duration.

The solution that has been devised includes the construction of a special manhole on the shaft of the combined sewer pipe. This special manhole is named diversion manhole, or manhole of flow separation, and its function is depicted in Figure 1 for both dry periods and storm events, where Q_s and Q_r denote the flowrates diverted to the main sewage collector pipe during dry periods (sewage flow) and storm events (sewage and stormwater flow), respectively. Specifically, the role of the adopted manhole is the following: During dry periods, when the rainwater discharge is zero, an overflow weir (Figure 1) diverts the sewage flow and directs it to a sewage connection-pipe extending between the diversion manhole and the main sewage collector, which can be considered nearly perpendicular to the direction of the initial combined sewer pipe. During and soon after a storm event, the overflow weir/wall diverts only a small portion of the diluted sewage discharge (i.e., the sewage-stormwater mixture), to the nearly perpendicular sewage connection-pipe. The excess amount of the mixture continues its course over the overflow wall towards the nearest water receptor, e.g., the sea, a detention pond, or a receiving stream.

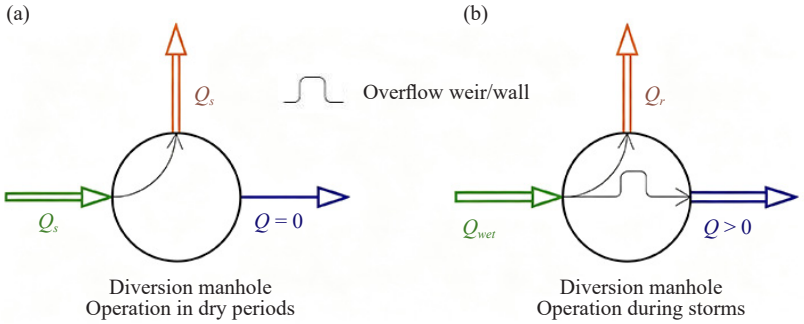


Figure 1. Hydraulic operation of the diversion manhole during: (a) dry periods and (b) storms

The aforementioned technique ensures that all the sewage flow of the combined sewer system is collected, conveyed and treated in the WWTP in the absence of rainfall. The mixture of wastewater and stormwater conveyed by combined sewer systems during or immediately following heavy rainfall events is substantially diluted. Consequently, it may be discharged into the receiving water body in compliance with the effluent quality standards established under Council Directive 91/271/EEC [13], as well as Greek Ministerial Decision 5673/400/1997 (Government Gazette 192/B/14-03-1997) [14], through which Greece has harmonized its national legislation with the requirements of Directive 91/271/EEC. The latter was subsequently recast by Directive (EU) 2024/3019 [15].

2.2 *Design and operation of the diversion manhole*

In the previous section, the basic idea of the diversion manhole was briefly outlined. The present section is dedicated to the presentation of the manhole's design and operation principles. The location of the diversion manhole, along the combined sewer pipeline, is depicted in Figure 2, where the basic parts of the appurtenance are also shown. The combined sewer pipe, which conveys the sewerage flow mixture from left to right, is the preexisting pipe of the combined sewerage system, while the new sewage connection-pipe-usually of smaller diameter-is constructed nearly perpendicular to the main combined sewer and conveys sewage to the main sewage collector. The part of the combined sewer pipeline that is located downstream of the diversion manhole operates during and immediately after rainfall events, and directs the diluted mixture of sewage and rainwater that flows over the weir to the water receptor. The overflow weir (or diversion weir) is constructed inside the diversion manhole and it is raised up to a specific crest height, while sewage and overflow channels are properly cast at the bottom of the manhole to avoid formation of retention/pool areas.

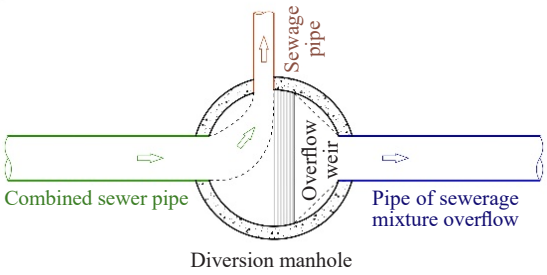


Figure 2. Typical plan view of the diversion manhole

The operation of the diversion manhole is as follows: (i) during dry periods, the combined sewer pipeline carries only sewage, with flowrates much lower than its drainage capacity. The sewage entering into the manhole is diverted through the overflow weir. The dimensions of the manhole, the diameter of the sewage connection-pipe, as well as its

slope should ensure that the maximum flowrate of sewage (i.e., attained in the absence of rainfall) dictated by the water quality study can be received and conveyed. It is highlighted that, for hydraulic reasons detailed below, the sewage connection-pipe should not be overdesigned. Rather, it should be designed exactly for the maximum flowrate of sewage (i.e., attained in the absence of rainfall) dictated by the water quality study. This issue consists a difficult aspect when designing diversion manholes. Finally, the perpendicular sewage connection-pipe of the diversion manhole ends to the main sewage collector, namely the main sewage pipe of the city that connects to the WWTP. (ii) During and immediately after a storm event, the combined sewer system carries a mixture of rainwater and sewage. The flowrate of the sewerage mixture is considerably larger than that corresponding to dry conditions, when only sewage is carried by the combined sewer system. The sewerage flow mixture is driven firstly to the perpendicular sewage pipe, as a result of the manhole configuration described above. In this case, the perpendicular pipe receives discharge equal to its design capacity, which is determined by its diameter and the slope of the energy grade line of the flow. The hydraulic discharge of the mixture in excess of the design capacity of the sewage connection-pipe cannot enter the latter and, therefore, the free surface of the water in the diversion manhole gradually rises. At some point, the water level rises above the crest of the overflow weir, and the overflow is channeled into the combined sewer pipe (or overflow pipe) located on the right of the diversion manhole (see Figure 2) and gradually discharges to the water receptor. It is noted that there is no mechanism to prevent the sewerage flow mixture from entering the sewage pipe. Therefore, during rain events, the sewage connection-pipe is expected to operate under pressure (i.e., pressurized pipe flow) exhibiting hydraulic discharge rates larger than the maximum flowrate of sewage (i.e., attained in the absence of rainfall) used for its design. The former are determined by its diameter and the slope of the energy grade line of the pressurized flow.

It is clarified that, in the case of diversion manholes, there exist two outflow pipes: the sewage connection-pipe, which conveys the sewage (sewage and stormwater mixture) during dry periods (storm events), and the overflow pipe, which works solely during storm events conveying the overflow portion of the sewerage flow mixture towards the water receptor. Regarding regular (i.e., no diversion) manhole facilities of sewer systems, there is a single outflow regardless the number of inflow pipes. To what concerns diversion manholes, the problem of distributing the inflow discharge to the two outflow pipes remains an open challenge. A practical approach towards its resolution, which has been effectively applied in the city of Patras, is analyzed in detail in the subsequent sections.

2.3 *Sensitivity of diversion manhole to blockages*

As the perpendicular sewage (collection) pipe has cross sectional area much smaller than that of the combined sewer pipe (see Figure 2 and Section 2.2), it remains sensitive to blockages due to objects carried either by the rainwater or sewage flows. Partial or total blockage of the sewage pipe results in sewage overflow towards the water receptor even during dry periods, and renders gradually the operation of the diversion manhole defective. To prevent or minimize such cases, frequent inspection, maintenance and cleaning of the diversion manhole are necessary. Additionally, the sewage and overflow channels at the manhole bottom should be carefully cast to avoid formation of retention/pool areas. These practical aspects can greatly contribute to the reduction of blockages in the diversion manhole.

A typical practical solution is the construction of a retaining basin for solids along the combined sewer pipe, immediately upstream of the diversion manhole. A disadvantage of this solution is that the retaining basin cannot block floating objects, which are expected to remain in the diversion manhole until they are either manually removed (during maintenance and/or cleaning) or transported to the terminal water receptor (by the overflow during storm events). Furthermore, the retaining basin works properly under a regular inspection and cleaning schedule, as solids accumulate and fill gradually its interior, substantially affecting the sewage flowrate to the diversion manhole. It has been proven in practice that the operation of the retaining basin can become more efficient by placing some type of grates (e.g., a proper bar rack/grate cage device). Nevertheless, the presence of such a retaining device requires even more systematic periodic cleaning. It is noted that the retaining basin and the diversion manhole should be inspected and cleaned at the same time. The dimensions of the retaining basin as well as those of the grate cage depend on the dimension of the combined inflow sewer pipe and the expected solid load flowrate. In order to ensure proper operation of the system that comprises the retaining basin and the diversion manhole, the wastewater flowrate should be undisturbed regardless the retention load of solids concentrated in the grate cage device. This requirement can be achieved with the combination of a large retaining basin with a proper grate cage along the sewer pipe, as well as with frequent and periodic cleaning of the system.

Both efficient operation, as well as adaptation to the fact that sewerage pipelines run along public roads and streets, dictate the use of elongated retaining basins with the larger dimension oriented along the sewer pipeline. From a practical point of view, the internal dimensions of the basin is recommended to be equal to $2D \times 3D$ and the basins' depth below the bottom of the pipe to be equal to D, where D is the diameter of the combined sewer pipe. Finally, it is pointed out that the cleaning process of the diversion manholes as well as of the solid retention basins can be annoying to the locals (due to smells) and disruptive for the traffic (due to road occupation).

3. Results and discussion

3.1 *Variation of the hydraulic discharge of the sewage connection-pipe*

During or soon after a storm event, the cross-section of the combined sewer is almost full with the sewerage flow mixture, while pressurized flow is generated in the sewage connection-pipe. The alternation of the flow mode from a free surface flow to a purely pressurized flow, which is attributed to the rise of the water level inside the diversion manhole, results in an increase of the flowrate in the sewage connection-pipe. The latter increase can become excessive in cases where the diameter of the sewage connection-pipe is selected arbitrarily; i.e., without prior knowledge of the expected result. It is evident that even a moderate increase in the flowrates of the sewage connection-pipes of several diversion manholes may overload the main sewage collector, the pumping stations, as well as the WWTP.

Figures 3 and 4 depict sections along the sewage connection-pipe extending between the diversion manhole and the main sewage collector for two slopes of the energy grade lines, namely one corresponding to a dry period (Figure 3) and another corresponding to a storm event or to a period soon after that (Figure 4). In the latter case, the free surface level of the sewerage flow mixture inside the diversion manhole has gradually raised close to the top of the combined sewer pipe.

In Figure 3, the slope of the energy grade line is approximately equal to the construction slope of the pipeline, considering uniform flow (i.e., 2%), as it is hydraulically expected for a free-surface flow in a pipe. Denote by Q_s the design capacity of the sewage connection-pipe under free-surface flow conditions. To avoid overdesign of the sewage connection-pipe, which would result in unnecessary increase of the flowrate in the main sewage collector, Q_s should equal the maximum flowrate of sewage (i.e., attained in the absence of rainfall) dictated by the water quality study. For illustration purposes, and without any loss of generality, suppose that the sewage connection-pipe has diameter d = 250 mm, and that its design filling ratio (i.e., defined as the water depth in the pipe divided by the pipe's diameter) should not exceed 70% (according to the Greek regulations; see [16]). By applying Manning's formula (see [17], [18]) with roughness coefficient n = 0.015 $m^{-1/3}s$ (common Manning's roughness coefficient values for the design of sewerage networks in Greece range from 0.015-0.02 $m^{-1/3}s$; see [16]), and construction slope of the pipeline i_s = 2%, one concludes that $Q_s \approx 50$ l/s. In Figure 4, the slope of the energy grade line is much larger (i.e., 20%), as the free surface level of the sewerage flow mixture in the diversion manhole is significantly higher. Using Manning's formula for pressurized flow conditions (i.e., filling ratio equal to 100%), sewage connection-pipe diameter d = 250 mm, and slope of the energy grade line equal to 20%, one finds that the discharge rate in the sewage connection-pipe during and soon after the corresponding storm event is in order of $Q_r \approx 200$ l/s. This flowrate value may become higher as the free surface level in the diversion manhole rises. For example, in old sections of combined sewer networks-mainly found in city centers-where the sewage network capacity is low, the free surface of the sewerage flow mixture in the diversion manhole can reach up to the road level.

It is noteworthy, however, that quadruplication of the hydraulic discharge (i.e., $Q_r/Q_s \approx 200/50 = 4$) of several diversion manholes in a city may significantly affect the operation of the sewage collector pipe as well as that of the receiving WWTP. The latter is designed to treat domestic sewage rather than excessive discharge rates of a highly diluted sewerage mixture (i.e., sewage and stormwater). To reduce the range of variation of the combined hydraulic discharge that reaches the WWTP, two alternative design approaches of the diversion manhole, are presented in Sections 3.2 and 3.3 below.

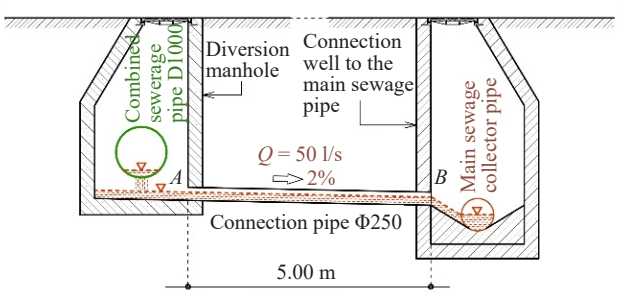


Figure 3. Operation of a diversion manhole during dry periods. The free surface of the flow is marked with orange dotted line

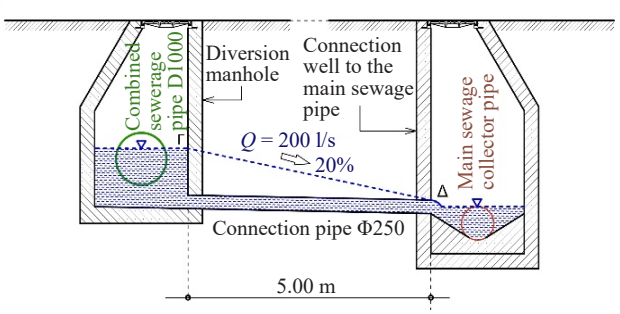


Figure 4. Operation of a diversion manhole during and soon after a storm event. The free surface as well as the energy grade line of the flow are marked with blue dotted lines

3.2 *1st design approach*

The first design approach is illustrated schematically in Figure 5, and its main aspects are summarized below. Proper function of the system is ensured through the presence of a hydraulic drop D_h of the sewerage flow mixture between the inflow combined sewer pipe and the overflow drainage pipe, as well as through the length, L_v, of the weir overflow crest, which should be sufficiently large. Proper design aims to control the raise of the mixture's free surface inside the diversion manhole during storm events, retaining it at low levels. This can be achieved if the thickness y of the overflow vein becomes minimum. To this purpose, y should not exceed $0.3D$ (see Figure 5), where D denotes the diameter of the overflow drainage pipe of the mixture, as its design filling ratio (i.e., defined as the water depth in the pipe divided by the pipe's diameter) should not exceed 70% (according to the Greek regulations; see Section 3.1 and [16]). The length L_v of the weir crest should be large enough to ensure that the flow area $L_v \times y$ suffices to convey the overflow discharge. In Figure 5, the corresponding design characteristics of the diversion manhole are presented, together with the location of the free surface during dry periods (i.e., sewage flow) and storm events (flow of sewage and stormwater).

Following the example presented in Section 3.1 (see also Figures 3 and 4), when implementing the 1st design approach, the design capacity of the sewage connection-pipe under free-surface flow conditions is not altered (i.e., it remains $Q_s \approx 50$ l/s, for $d = 250$ mm, design filling ratio equal to 70% according to the Greek regulations, Manning's roughness coefficient $n = 0.015$ m$^{-1/3}$s and slope of the energy grade line equal to the slope of the pipeline is = 2%), while the discharge rate in the sewage connection-pipe during and soon after the corresponding storm event is on the order of $Q_r \approx 80$ l/s; i.e., 60% lower than the value of 200 l/s attained in the absence of the diversion manhole (see Section 3.1). The aforementioned value of Q_r was obtained using Manning's formula for pressurized flow conditions (i.e., filling ratio equal to 100%), sewage connection-pipe diameter $d = 250$ mm, overflow vein thickness $y = 0.3d < 0.3D$, and energy line slope equal to $2\% + 0.30d/5.00 = 3.5\%$ (see Figure 5).

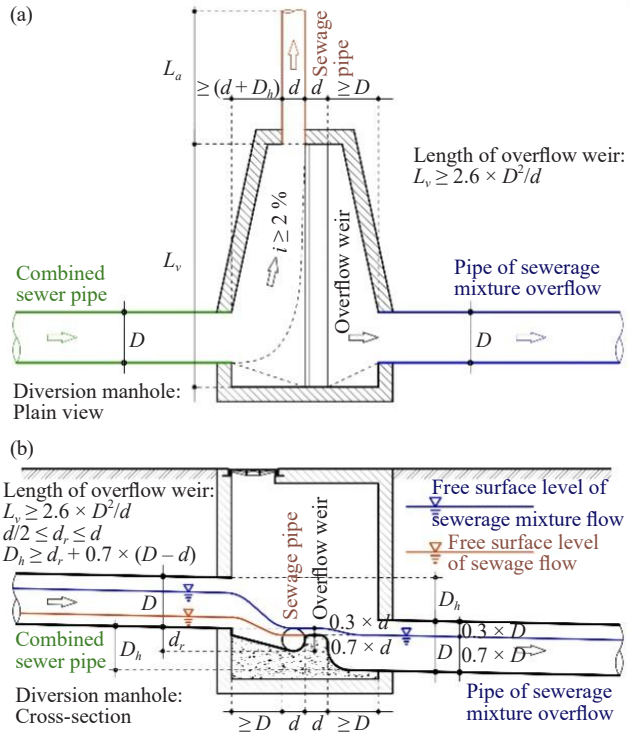


Figure 5. 1st design approach for the construction of a diversion manhole: (a) plan view and (b) cross-section in the direction of flow

The main disadvantage of the 1st design approach is that the required hydraulic drop D_h, in most cases, can only be achieved through (partial) reconstruction of the downstream overflow pipe. In cases where this is not possible, an alternative design approach can be adopted (see next Section), where the implementation of hydraulic drop, D_h, is not necessary.

3.3 2*nd design approach*

Figure 6 illustrates schematically the hydraulic operation of the sewage connection-pipe during the dry season (70% filling ratio) as well as during a storm event (fully filled). Application of Manning's formula gives:

$$Q_r/Q_s \approx \left(i_r/i_s\right)^{0.5} = \left(H_r/H_s\right)^{0.5} \tag{1}$$

where, $i_s = H_s/L_a$ and $i_r = H_r/L_a$ are the slopes of the energy grade line during dry periods (sewage flow) and during storm events (flow of sewage and stormwater), respectively (see Figure 6), and L_a is the length of the sewage connection-pipe between the two manholes. Despite its approximate validity, Eq. (1) clearly indicates that minimization of the Q_r/Q_s ratio can be achieved by minimizing the H_r/H_s ratio.

Under this setting, Figure 7 shows the plan view and the corresponding cross-section of a diversion manhole designed without the implementation of a hydraulic drop, D_h.

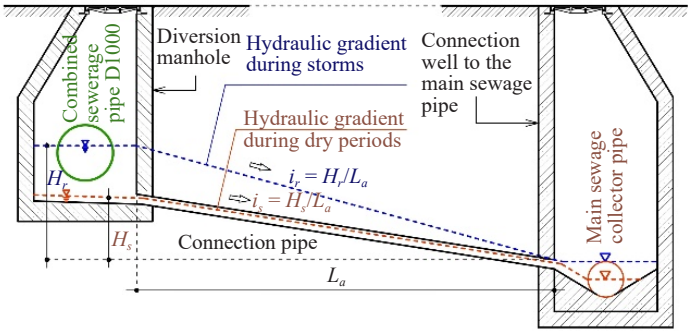


Figure 6. 2nd design approach for the construction of a diversion manhole: Cross-section along the sewage connection-pipe

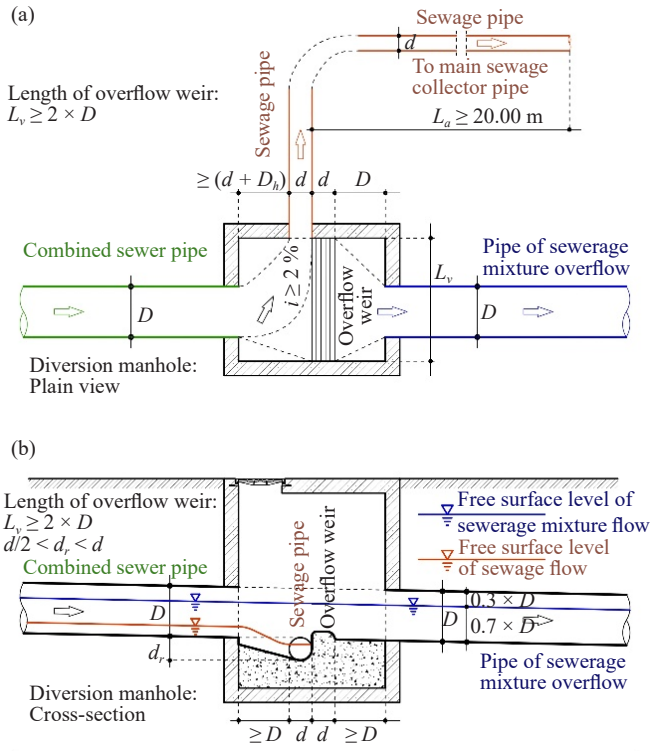


Figure 7. 2nd design approach for the construction of a diversion manhole: (a) plan view and (b) cross-section in the direction of the flow

Similar to the numerical example presented in previous sections, suppose that the length, construction slope and diameter of the sewage connection-pipe equal L_a = 40 m, i_s = 2% and d = 250 mm, respectively, and that the diameter of the inflow combined sewer pipe is D = 1,000 mm with design filling ratio equal to 70%. In this case, the slope of the energy grade line along the sewage connection-pipe during a storm event is $i_r = i_s + 0.7D/L_a = 2\% + 0.7/40 = 3.75\%$. By applying Manning's formula using $n = 0.015$ m$^{-1/3}$s, one obtains $Q_r \approx 100$ l/s; i.e., 50% lower than the value of 200 l/s attained in the absence of the diversion manhole (see Section 3.1), but 25% higher than the value of 80 l/s attained by the 1st design approach.

4. Conclusions

In this paper, an appurtenance for combined sewer systems is proposed, to complement proper operation of

the sewerage system as well as to ensure that the design capacity of Wastewater Treatment Plants (WWTPs) is not exceeded. The proposed diversion manhole has been successfully applied by the Municipal Enterprise of Water Supply and Sewerage of Patras (DEYAP) to recently constructed diversion manholes in the city of Patras, based on previous experience of malfunctions detected in older constructions. Based on preliminary analysis considerations presented in the previous sections, we conclude that:

• The diversion manhole constitutes a "safety valve" contributing to the maintenance and proper operation of WWTPs in cities where combined sewer systems exist.

• The proposed appurtenance operates as a regulator of the sewerage flow in the combined sewer system, attaining its diversion towards the nearest terminal water receptor, when the combined discharge of sewage and stormwater exceeds a desired threshold.

• Construction of a retaining basin for solids along the combined sewer pipe, immediately upstream of the diversion manhole, facilitates operation of the latter by preventing possible blockages due transported material and/or objects.

• Reduction of the ratio Q_r/Q_s, where Q_s and Q_r denote the flowrates diverted to the main sewage collector pipe during dry periods (sewage flow) and storm events (sewage and stormwater flow), may be achieved by implementing one of the two design approaches presented, depending on the existing configuration of the combined sewer system, with the first approach being slightly more efficient than the second, but requiring (partial) reconstruction of the downstream overflow pipe.

Since no field data are currently available regarding the implementation of the proposed diversion manhole, this study should be regarded as a preliminary hydraulic design approach based on practical implementation experience rather than a fully validated performance assessment. Further numerical investigation is expected to provide a more comprehensive understanding of the proposed appurtenance's hydraulic behavior and contribute to the development of refined, more detailed design criteria. The latter will be the subject of future communications.

AI disclosure statement

No Generative AI and/or AI-Assisted Technologies have been used for the preparation of this article.

Author contributions

Conceptualization, methodology, formal analysis, data curation N.Th.F., A.L. and C.I.L.; investigation, C.I.L.; writing-original draft preparation, N.Th.F. and A.L.; writing-review and editing, visualization, N.Th.F., A.L. and C.I.L. All authors have read and agreed to the published version of the manuscript.

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Data availability

No data was required or used for the presented analysis.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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