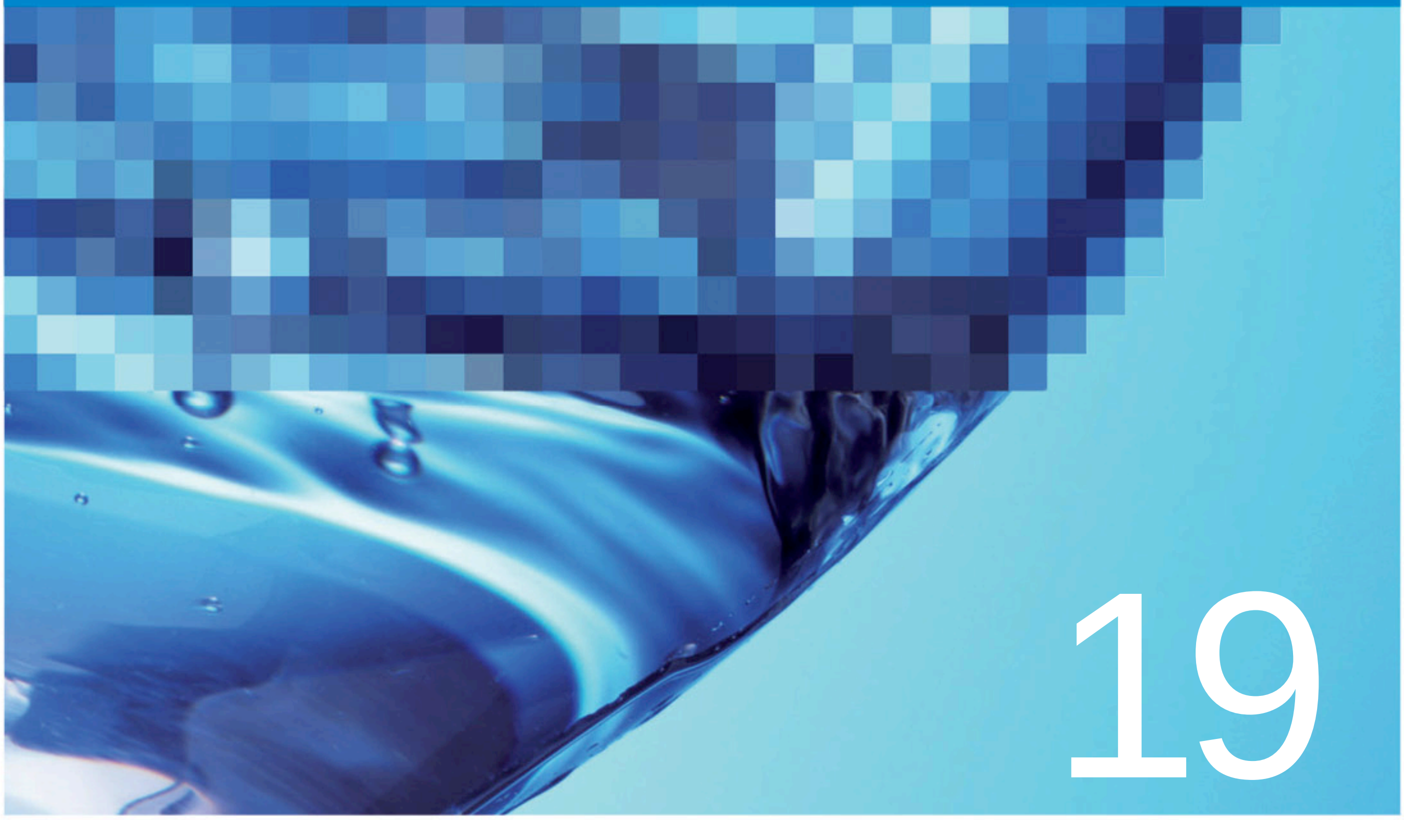
Booklets Research & Development & Innovation



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Canal de Isabel II gestión

A new criterion for calculating urban sewage flows

19

A new criterion for calculating urban sewage flows

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Aknowledgements

The authors are grateful to the members of the Engineering and Construction unit, the Operation of Sewage Treatment unit, the Planning and Municipal Coordination unit and the Research, Development and Innovation unit, all of them part of Canal de Isabel II Gestión, for their participation during different development phases of this study.

Print ISSN: 2254-8955

Electronic ISSN: 2340-1818

Legal Deposit: M-34453-2013

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Presentation

The collection **Booklets of Research, Development & Innovation** of Canal de Isabel II Gestión S.A. are a part of the company's knowledge management strategy and of its R + D & I Plan.

These Booklets represent an element for diffusion of projects and initiatives developed and promoted by the company, and aim at innovation in areas related to the water services in an urban environment.

They deal with the problems tackled by each project as well as the results obtained. The aim of publishing these Booklets is to share experience and knowledge with the entire water industry sector, with the scientific community and with all those who work in the fields of research and innovation. With these publications what it is hoped is contribute the improvement and efficiency in water management and, as a result, make it possible to offer a better service to the citizens.

The titles published in the series to date are shown in the following table.

BOOKLETS OF RESEARCH, DEVELOPMENT & INNOVATION PUBLISHED

Collection Number	*Research, Development and Innovation Booklets published*
1	Transferences of Water Rights between Urban and Agrarian Demands. The case of the Community of Madrid
2	Identification of Hydrometeorological Runs and Tendencies within the scope of the Canal de Isabel II system
3	Contribution of Canal de Isabel II to the International Demand Management Project (IDMF)
4	Microcomponents and Explanatory Factors on Domestic Water Consumption in the Comunidad de Madrid
5	Virtual Water and Hydrological footprint in the Comunidad de Madrid
6	Study on the saving potential of water for residential uses in the Comunidad de Madrid
7	Potentials of efficiency in using dishwashers in the Comunidad de Madrid
8	Accuracy in the measurement of individual water consumption in the Madrid Region
9	Research project to define and assess the applicability of a Bioassay Test to determine the toxicity of water using Zebra Fish embryos
10	Water Use Efficiency in Gardening in the Region of Comunidad de Madrid
11	Remote sensing techniques and geographical information systems for assessing water demand for outdoor uses in the Comunidad de Madrid
12	Cyanotoxin Dynamics Study in two of the Canal de Isabel II's supply reservoirs in the autonomous region of the Comunidad de Madrid
13	Development of a validation, estimation and prediction of hourly consumption by sector, for the distribution network of Canal de Isabel II
14	Monitoring of the consolidation urban development in the Comunidad de Madrid using remote sensing techniques
15	Sectorization of the hydraulic distribution and transport network in the Comunidad de Madrid
16	Integration of weather forecasting in the management modules supply system of Canal de Isabel II, via daily contributions models
17	Improvement in forecast capacity of monthly and seasonal runoff in the scope of Canal de Isabel II
18	Inflow of nutrients from the basin to Pinilla reservoir. Effect on the eutrophication process

TABLE OF CONTENTS

1. **EXECUTIVE SUMMARY** 9

1.1. EFFICIENT INFRASTRUCTURE PLANNING 11

1.2. VERIFICATION OF THE RELATION BETWEEN WATER SUPPLY FLOWS AND, SEWAGE FLOWS 12

1.3. CONSTRUCTION OF A NEW ALTERNATIVE CRITERION FOR CALCULATING URBAN SEWAGE FLOWS 13

1.4. VERIFICATION OF THE VALIDITY OF THE NEW CRITERION 15

1.5. FORMULATION OF A NEW CRITERION FOR CALCULATING URBAN SEWAGE FLOWS FOR DESIGN PURPOSES 17

1.6. EVALUATION OF THE SIGNIFICANCE OF THE CHANGE IN CRITERION 18

2. **AIM, JUSTIFICATION AND SCOPE OF THE STUDY** 20

2.1. AIM OF THE STUDY 21

2.2. METHOD AND SCOPE 22

2.3. WHAT HAPPENS NOW AND WHAT MAY HAPPEN IN THE FUTURE 23

2.4. DESIGN FACTOR OF SAFETY 23

3. **BACKGROUND AND VERIFICATION OF THE SUITABILITY OF THE TRADITIONAL CRITERION** 24

3.1. CONTEXT ANALYSIS OF WATER SUPPLY / TREATMENT OF SEWAGE 26

3.2. RELATIONSHIP BETWEEN THE FLOW'S MEASUREMENT OF THE WATER SUPPLIED AND THAT OF THE TREATED WASTE WATER, ACCORDING TO DIFFERENT RELIABILITY FILTERS 29

4. **PROPOSAL OF AN ALTERNATIVE CRITERION** 33

5. **VERIFICATION OF THE VALIDITY OF THE NEW CRITERION** 36

5.1. VALIDATION OF THE PROPOSED CRITERION FOR DEVELOPED URBAN GROUND 37

5.1.1. Application of the new criterion to present circumstances 38
5.1.2. Verification through current measurements at sewage treatment plants 42
5.1.3. Evaluation of the criterion in isolated supply areas 44

5.2. COMPARISON OF THE RESULTS' ADJUSTMENT OBTAINED WITH THE PROPOSED NEW CRITERION AND WITH THE TRADITIONAL ONE 45

6. FORMULATION OF THE NEW CRITERION FOR CALCULATING SEWAGE FLOWS FOR DESIGN PURPOSES 49

6.1. CRITERION FOR CALCULATING FLOWS ON DEVELOPED URBAN GROUND FOR DESIGN PURPOSES 52

6.1.1. Multi-housing usage 52

6.1.2. Single-housing usage 53

6.1.3. Industrial, Institutional and Tertiary usage 53

6.2. CRITERION FOR CALCULATING FLOWS IN UNDEVELOPED PLANNING AREAS FOR DESIGN PURPOSES 53

6.2.1. Multi-housing usage in undeveloped planning areas 54

6.2.2. Single-housing usage in undeveloped planning areas 54

6.2.3. Industrial, Institutional and Tertiary usage in undeveloped planning areas 54

6.3. SUMMARY OF THE APPLICATION FOR CALCULATING 55

7. EVALUATION OF THE SIGNIFICANCE OF THE CRITERION CHANGE 57

7.1. VERIFICATION OF THE CHANGE PRODUCED IN THE RATIO BETWEEN THE DESIGNS FOR URBAN SEWAGE FLOWS AND SUPPLY FLOWS 59

7.1.1. Significance of the change of criterion for the “supply sector” scale 59

7.1.2. Significance of the change of criterion for the “Sewage Treatment Plant” scale 61

7.2. EVALUATION OF THE IMPACT OF THE CHANGE OF CRITERION WHEN PLANNING IN A REAL SEWAGE TREATMENT SYSTEM. COMPARISON WITH THE TRADITIONAL CRITERION 63

7.2.1. Analysis for the case of water Sewage Treatment Plants on the present horizon 63

7.2.2. Comparison of design results for sectors on the present horizon 65

7.2.3. Evaluation of the significance for future planning 69

8. CONCLUSIONS 70

9. APPENDICES 72

9.1. APPENDIX 1. DATA AVAILABLE FOR THIS STUDY 73

9.2. APPENDIX 2. RELIABILITY OF THE DATA 75

9.2.1. Reliability of measurements of supply to sectors 75

9.2.2. Reliability of sewage flow measurements at WWTP 76

9.2.3. Combined data reliability 77

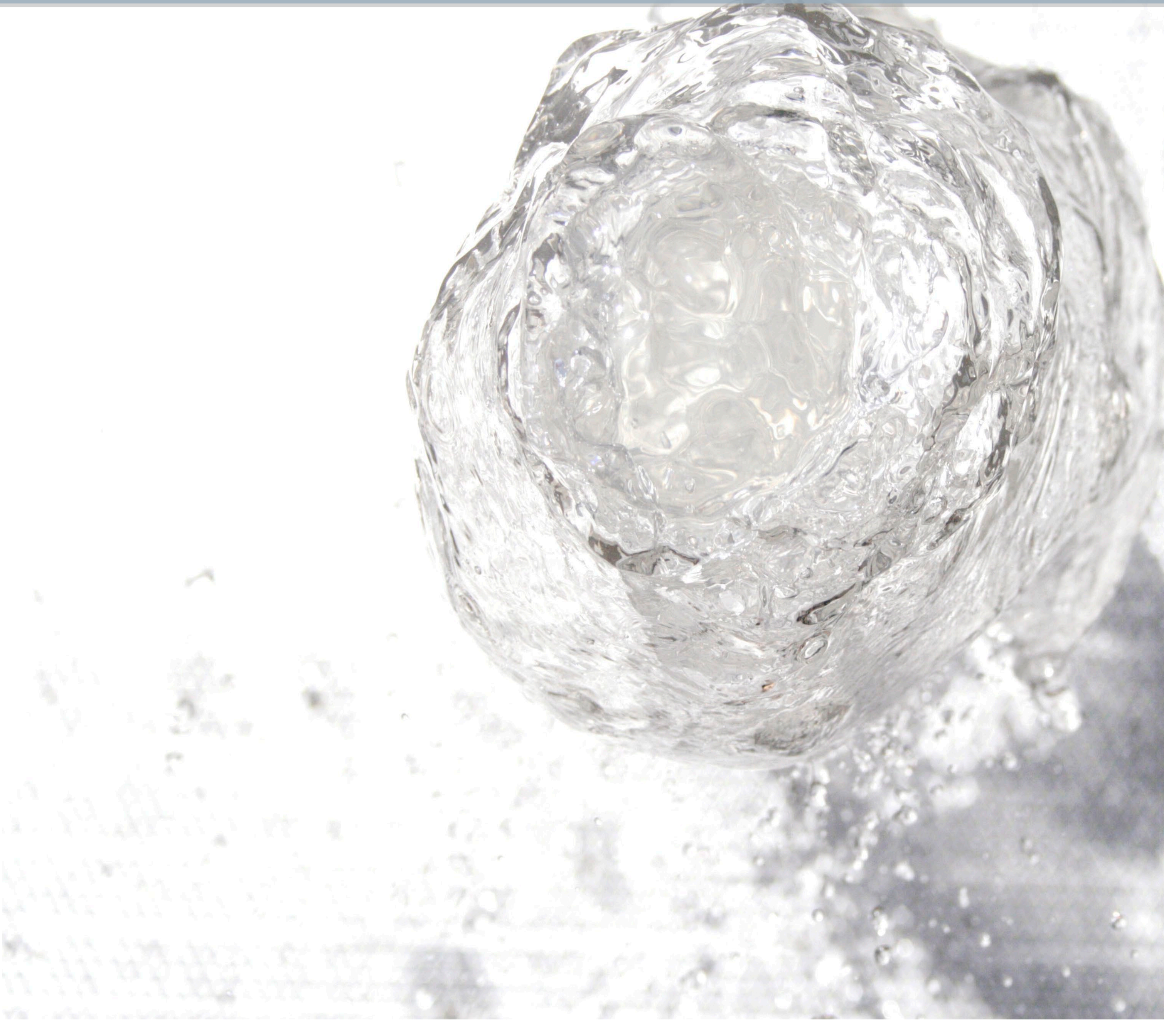
9.3. APPENDIX 3. LIST OF FIGURES 78

9.4. APPENDIX 4. LIST OF TABLES 80

9.5. APPENDIX 5. BIBLIOGRAPHY 81

9.6. APPENDIX 6. GLOSSARY OF TERMS USED IN THE DOCUMENT 82

1. Executive Summary



Project Outline

Project title	**A new criterion for calculating urban sewage flows**
Research line	Efficiency in strategic management of infrastructures
Canal de Isabel II Gestión areas involved	Research, Development & Innovation unit Engineering and Construction unit Operation of Sewage Treatment unit
External participation	Participation of companies outside of Canal de Isabel II Gestión, S.A. has not been necessary.
Aim and justification of the Project	Contribute to improved efficiency when planning the investment necessities in water sanitation and sewage treatment systems through a new method of determining urban sewage flows in the Community of Madrid.
Contribution to the state of the art	Proposal of a new criterion for calculating urban sewage flows in order to replace the old criterion that has been used for decades.
Summary of the Project development and relevant milestones	The new calculation criterion is defined on the basis of measured consumption according to type of usage, microcomponents of consumption (external usage), measured distribution sector flows, cartographic and topographic data of drainage basins, and flows controlled at WWTPs (Waste Water Treatment Plants). The idea is to establish different return rates according to types of water usage. The new criterion has been validated through real measurement data from WWTPs and distribution sectors. The quality of the new proposal has been checked through comparisons between the results obtained and those obtained using the traditional criterion.
Summary of the results obtained	It is shown that the application of the proposed new criterion is better fitted to the existing real scenario in the Community of Madrid than the traditional criterion. In the long run, the new criterion gives global sewage flow results that are lower (between 15 and 20%) than the results obtained when applying the traditional criterion (of 80% of the supplied water).
Research Lines open for continuing the work	Include the new criterion in the practical design of WWTPs, taking into account the consideration on contaminating loads.

Executive Summary

1.1. EFFICIENT INFRASTRUCTURE PLANNING

The comprehensive management of water supply, sanitation and sewage treatment services in the Community of Madrid includes the planning of investment in hydraulic infrastructure. These investments cover new constructions as well as the extension and updating of existing facilities. The investments have to be planned in a way that allows for the infrastructure and its operation to be able to respond to all needs with acceptable results both in quality and in service continuity, in each and every one of the present and future scenarios.

The planning process involves the following phases:

1. Definition of criteria and standards of service.
2. Definition of the scenarios to be analysed (scope, time horizons and request intensity).
3. Identification of time and place necessities.
4. Choice of measures to be taken.
5. Programming of these measures.

In this way, the amount of investment for both establishing new facilities and exploiting and for maintaining existing ones is programmed. The planning will be efficient if the defined criterion of service quality is achieved in all the situations that have been considered and with the least possible investment.

The measures have to be defined with a certain size and design where the most important part is the calculation of flows. The aim of this study is to achieve a higher efficiency based on a more accurate evaluation of the analysed water flows.

1.2. VERIFICATION OF THE RELATION BETWEEN WATER SUPPLY FLOWS AND URBAN SEWAGE FLOWS

The traditional criterion applied to estimate urban sewage flow is based on a constant factor of 80% of the supply flow in each area of the study.

The company Canal de Isabel II Gestión has at its disposal a large amount of precise data from the Community of Madrid which has provided very useful information on the water flows flowing through different strategic points of the different service networks. The availability of these data is the result of carrying out innovation projects in the realm of planning and operating water supply, sanitation and sewage treatment systems. Among the outstanding projects in this sense are the sectorization of the supply network, the study of home consumption microcomponents, the individual consumption monitor panel, and the corporate remote control system and corporate geographic information system. Thanks to these data, it was possible to check if the ratio between drinking water supply flow in urban areas and sewage flow, in the same areas, is a constant one.

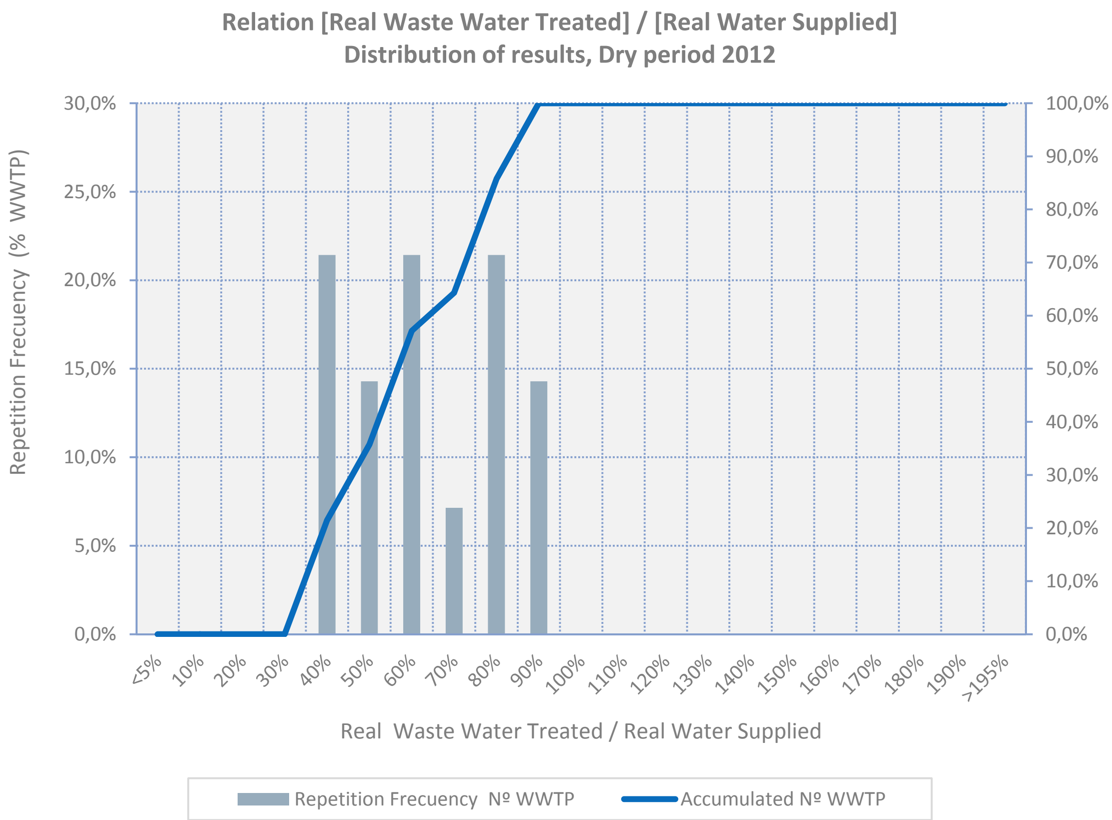
In order to carry out this verification, the flows of drinking water actually supplied were compared to the sewage flows flowing through the sanitation systems. The scope of this study is limited to the calculation of urban sewage flow, not taking into consideration rainwater drainage. In order to take this factor into account, all of the verifications were carried out with real data registered during the dry months of 2012 in the Community of Madrid.

The measurements of drinking water supplied were taken from the sectorized supply system of the company Canal de Isabel II Gestión. In this study, the term "***sector***" refers to areas of water consumption with a permanent configuration where water inflow and outflow are monitored through flow meters with an hourly frequency. Thanks to the representation in the geographic information system all the elements of the network that make up each sector are known, and are able to identify the connections to each home and every individual consumer inside.

At the same time, the remote control system has made it possible to register the flows measured at the WWTP at hourly intervals.

Because of this, the data pairs of "sewage flow" and "supply flow" could be analysed in groups of months (based on daily values and taking into account necessary considerations on the quality of the data). In this way, it was verified that, according to data from 14 WWTPs, the ratio between water supply flow and urban sewage flow is not a constant one in the water sanitation and sewage treatment systems that were measured, where more than 70% of the analysed cases of WWTP water inflow remained below the constant factor of 80% applied by the traditional criterion (figure 1).

FIGURE 1. **RELATION OF THE REAL QUANTITIES OF WASTE WATER TREATED / WATER SUPPLIED**



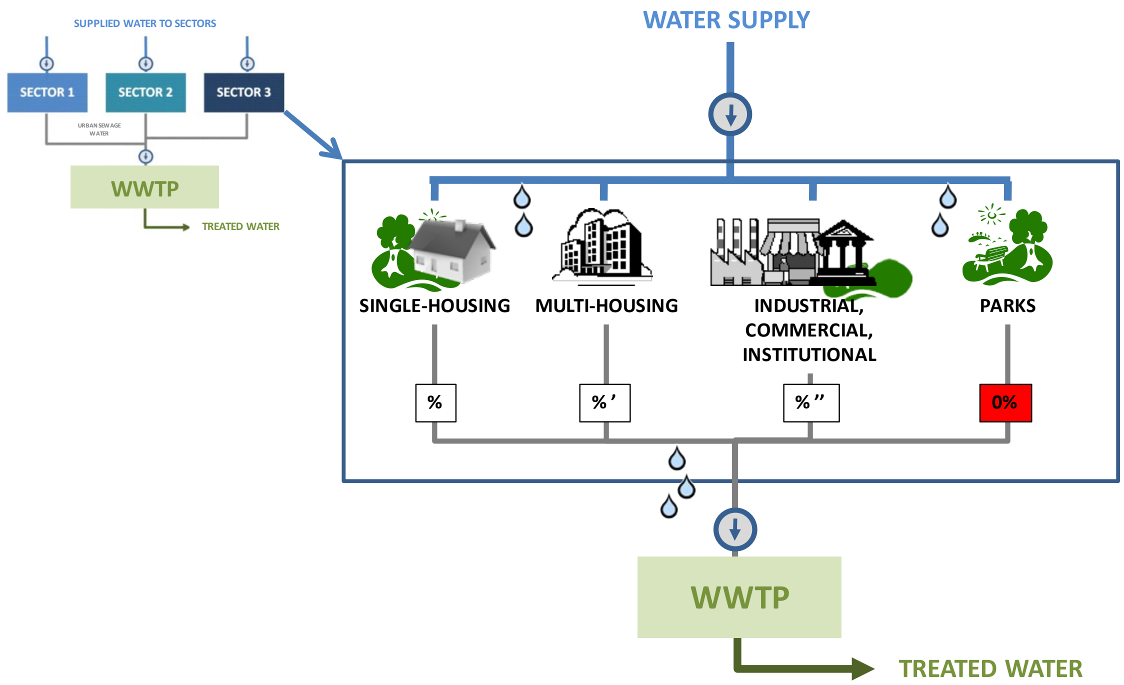
In view of these results, it was concluded that a more efficient alternative for calculating urban sewage flow should be sought, rather than depending exclusively on one single percentage ratio between sanitation flow and supply flow.

1.3. CONSTRUCTION OF A NEW ALTERNATIVE CRITERION FOR CALCULATING URBAN SEWAGE FLOWS

In order to find a new method of calculation the knowledge and experience in the design of supply systems was used. For supply systems, the flow is calculated by adding standardized individual consumptions to their corresponding design unitary consumptions. In a similar way, one can make the calculation of urban sewage flows by taking into account the individual properties with their design unitary consumptions and specific return rates. This would mean abandoning the concept of constant return rates for entire consumption areas or regions.

This proposed concept is shown graphically in the figure 2.

FIGURE 2. **ALTERNATIVE CRITERION FOR CALCULATING URBAN SEWAGE FLOW**



The new criterion would thus be based on considering the "properties" that generate the sewage water individually. "Property" here refers to the physical unit that consumes water or, in this case, that returns water to the sewer system. In the context of housing, a property would be each one of the apartments in a multi-housing building, or each one of the houses or cottages inhabited by a single family. For other non-domestic usages, property refers to a natural unit of water consumption or generation. In the case of the Community of Madrid and its regulations for a contracting water service, a non-domestic property means one service contract: one property for each business space, one property for each company, one property for each institutional public usage water outlet, one property for each irrigation system in parks or on roads, etc.

The properties are classified according to the type of usage made of the drinking water, which determines the proportion of water that will return to the sewer system. This means that each type of property has its own specific "return rate". The establishment of each return rate's numerical value is based on the conclusions of the study on microcomponents and final usages carried out in the Community of Madrid as well as other relevant studies. The microcomponents (and final usages) of drinking water refer to each one of the purposes the water is used for within a property.

In the context of domestic usage, the microcomponents distinguish between purposes such as showers, washing machines, dish washers, taps, lavatories, as well as exterior usage such as in patios and gardens. Based on the knowledge of the proportions of each one of these final usages, the percentage of supplied water that is returned from the housing units to the sewer system it is established, as well, it is distinguished between the return rates of multi-housing and the single-housing buildings.

As to the other usages, the establishing procedure is similar. A special case is the exterior usage of water in parks and public and private gardens, where it is assumed that the return rate to the sewer system is nil. The return rates for the different types of usage were established as follows:

- Domestic usage in multi-housing buildings: 1.00
- Domestic usage in single-housing buildings: 0.73
- Industrial, institutional and tertiary usage: 0.90
- Exterior usage (irrigation): 0.00

In order to establish the return rate of other usages and purposes that are really carried out or occur in urban areas, the intention of the new criterion to represent the percentage of water that finally flows through the sewer system has been taken directly into account. These “other usages” had a certain importance as they dealt with the most precise verification possible of this process, including water usages such as pipe drains, pipe cleaning, fraudulent usage, etc.

1.4. VERIFICATION OF THE VALIDITY OF THE NEW CRITERION

In order to verify this criterion as a calculation method, the quality of the adjustment of the real measurement data of urban sewage flows was checked against the values achieved by applying the specific return rates of the different drinking water usages according to the measurements in the individual properties. In this way, the ***real flow of consumption of drinking water*** measured at the users’ properties was converted into the ***calculated flow of sewage water***. Afterwards, whether this calculated sewage flow matches the real sewage flow flowing through the sewer system was checked.

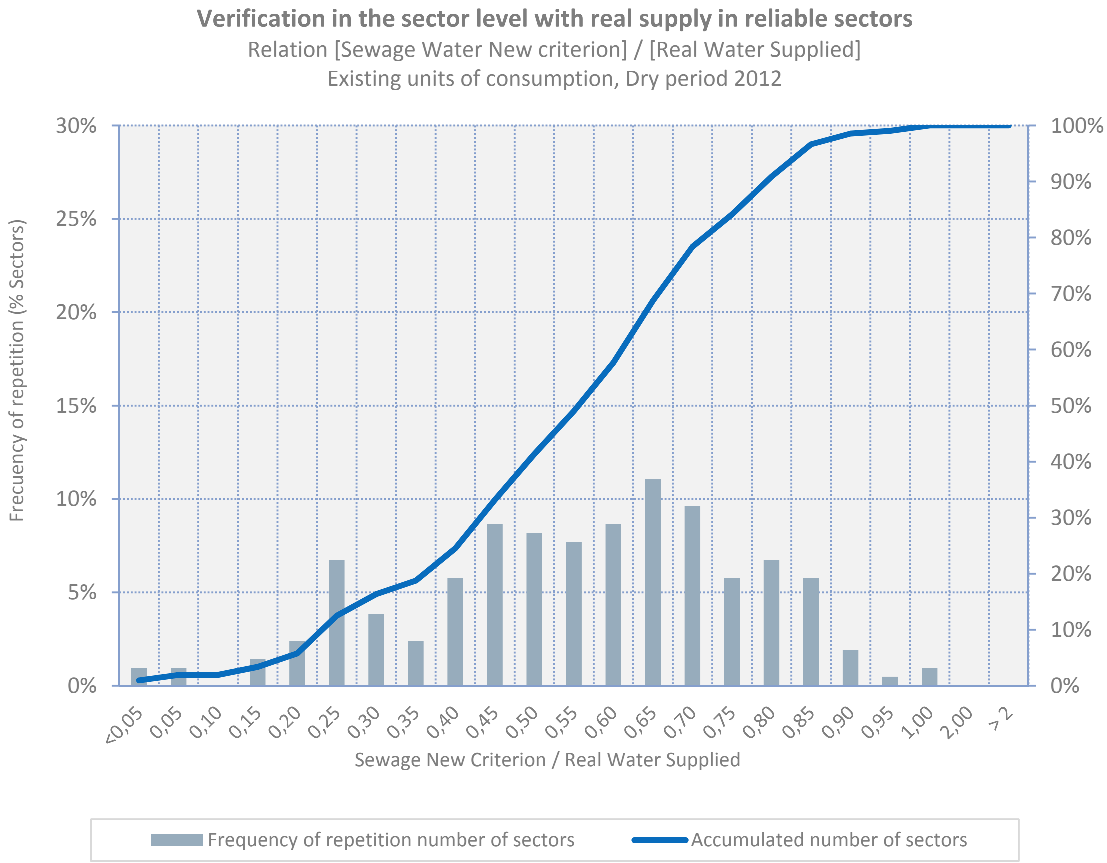
For this purpose the database of registered individual consumption measured by the users’ meters was employed, classifying this by type of usage. The flows supplied to the distribution networks in each sector which do not correspond to the users’ measured consumption (uncontrolled water) were obtained by the same calculation and estimation methods that are applied in order to establish the different efficiency indicators for the distribution sectors.

During this entire process a matrix was used to assign the drinking water consumption areas (supply sectors) and sewer systems (including sewage treatment plants’ drainage basins). The measured data had necessarily to be classified by their level of reliability, taking into account not only the assumed quality of the data, but also their representativeness and their reliability for the purpose. In order to prevent any influence of rainwater on the inflow flows measured at the WWTPs, only data series from dry periods in 2012 were used.

This calculation for validation turned out to be significantly more precise than the result of applying the constant rate of 80% of the supply flow in each sector. For the group of sewage treatment plants that work with actual flows lower than 2,000 m^3/day, the new criterion would avoid the oversizing caused by the traditional criterion. And for the four biggest sewage treatment systems analysed that work in conditions of greater reliability (with real flows of more than 9,000 m^3/day), the new criterion got significantly closer to the ideal calculation.

During this calibration phase, the application of the new criterion for calculating urban sewage flows in the distribution sectors revealed an important variation in the relation between the calculated sewage water and the measured water supply, with as much as 80% of the sectors showing a rate under 0.8 (figure 3).

FIGURE 3. VERIFICATION OF THE CRITERION THROUGH REAL SUPPLIES IN RELIABLE SECTORS



This validation process showed that taking into consideration specific return rates for different water usages in individual properties leads to more precise results for calculating urban sewage flows than the use of a single return rate for the entire area, applied to the total amount of drinking water supplies.

In this way, the new criterion guarantees greater accuracy in the prediction of urban sewage flows and therefore more efficiency in the planning process of water sanitation and sewage treatment infrastructures.

1.5. FORMULATION OF A NEW CRITERION FOR URBAN SEWAGE FLOWS DESIGN PURPOSES

After having confirmed the higher validity of the new criterion here described, attempts had been made to find a formulation suitable for calculating the flow of urban sewage water, for the purpose of infrastructure planning. The desired formulation was set out in relation to the variables used in planning and sizing water supply and distribution infrastructures.

This kind of planning, as it was said before, is based on the definition of certain working scenarios, each one with its own circumstances of time and space, which normally include both properties on already developed urban ground and new constructions. The division into these two categories is important because the design unitary consumptions of each property affect the design practices for the company's supply infrastructures, and it is Canal de Isabel II Gestión aims to apply this best practice also to the water sanitation and sewage treatment infrastructures.

For the purpose of planning and defining the supply infrastructures, the following distinctions between water usages are generally taken into account:

- Domestic usage in multi-housing buildings
- Domestic usage in single-housing buildings
- Industrial, institutional and tertiary usage
- Parks

These distinctions match the ones applied in urban planning which will be used further ahead for the definition of future scenarios in the Community of Madrid.

Each one of these drinking water usages relies on designed individual water consumptions design for properties either already existing or about to exist (as they refer to previous developed urban ground). The quantification of these design unitary consumptions relates to the results of statistical studies on real long-term consumption measured in the Community of Madrid, divided into towns for domestic usage, and into 11 larger areas for non-domestic usage. These supply design unitary consumptions represent the possible consumptions at the present time, in conditions of maximum consumption for design purposes. The method described in this document identifies "return rates" that are suitable for transforming the supply design unitary consumptions into individual urban sewage flows for design purposes, both for existing properties and for imminent future properties on already developed ground.

As to calculating urban sewage water generation on future properties, the supply design unitary consumptions that have been defined for these properties were used, applying the return rates that correspond to each type of usage, but modified in order to adapt them to the differences in the definitions of those design unitary consumptions. In the case of future design unitary consumptions, a deduction was applied that corresponds to leaks and other possibilities which should not be included in the calculation of sewage flows, but had in fact been taken into account when defining the supply design unitary consumptions.

Therefore the proposal consists of introducing a new calculation method for urban sewage flows, based on different return rates for each type of usage of the supplied drinking water and for each situation as far as consolidation or planning of future urban ground is concerned, as can be seen in the table 1.

TABLE 1. RETURN RATES

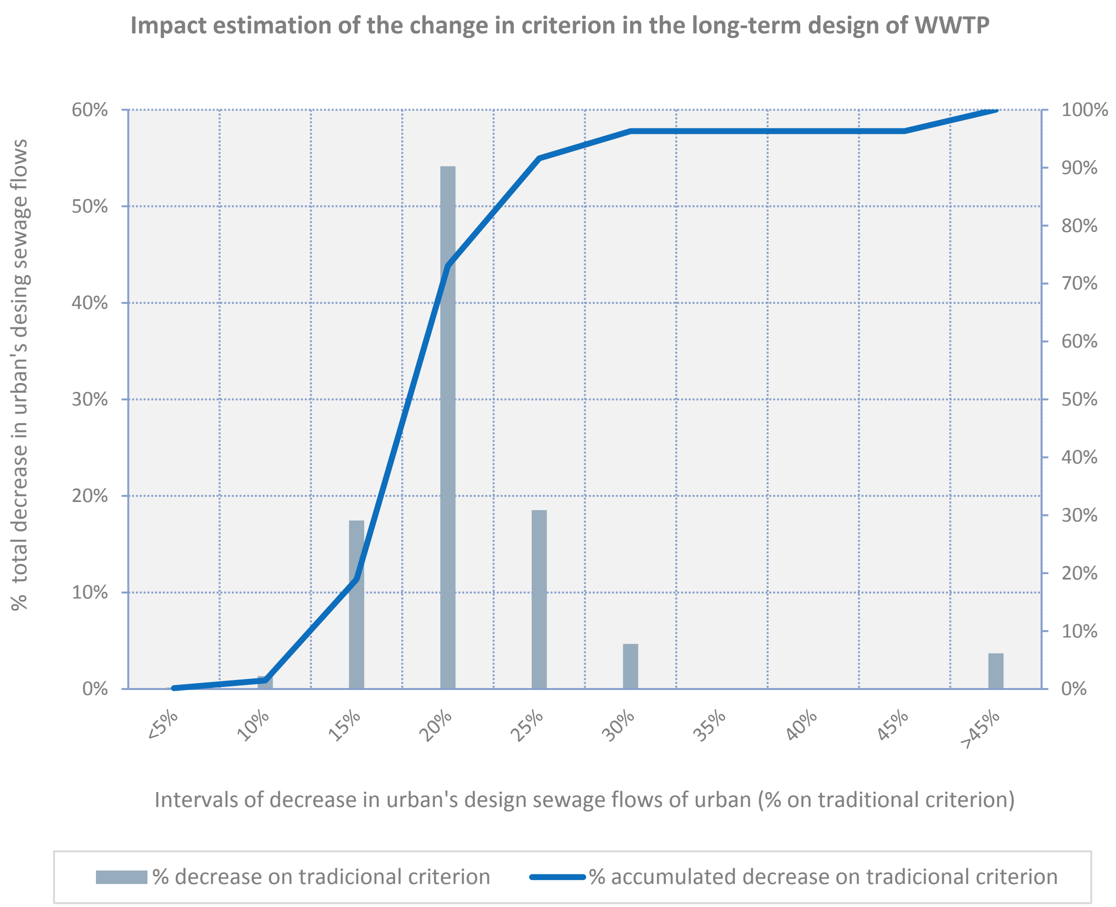
Concept	*E rn rates for design unitary consumptions*	
	Usage on developed ground	*Usage for future planning*
Multi-housing usage	100%	95%
Single-housing usage	73%	80%
Industrial, Institutional and Tertiary usage	90%	85.5%
Other usage	0%	0%

1.6. EVALUATION OF THE SIGNIFICANCE OF THE CHANGE IN CRITERION

After having validated the criterion and formulated its application for calculating flows in future scenarios, it was proceeded to quantify the impact that would result from adopting the new method of determining design flows for the sewage treatment system of the Community of Madrid. Taking into account a long-term horizon (the year 2027), the daily water flow requirements for a day of maximum consumption, calculated with the proposed new criterion and the traditional one were compared, both of them for sewage treatment plants that have to be enlarged and those that are being planned (according to the investment planning process of the company).

In this way, it has been concluded that the adoption of a calculation method for urban sewage flows, based on individualized return rates for each type of water usage, leads to results that reduce the global flow by 15%, compared to the calculation carried out with the traditional criterion. 74% of the measures planned for this horizon show a reduction of sewage flow of between 10% - 25%, and are therefore responsible for 90% of the calculated total reduction. In particular, 37% of the planned measures show a reduction of sewage flow of between 15% - 20%, which adds up to 54% of the total reduction. These numbers are illustrated by the figure 4.

FIGURE 4. THE NEW CRITERION'S CALCULATED IMPACT



2. Aim, Justification and scope of the study

2.1. AIM OF THE STUDY

The comprehensive management of water sanitation and sewage treatment services includes the exact sizing of the infrastructures upon which the actions needed to provide the services required are based. This process of sizing sewer systems and sewage treatment plants must be carried out in a way that allows a guarantee of success for all the different scenarios which the infrastructures will have to support during their life expectancy.

The planning process involves the following phases:

1. Definition of criteria and standards of service.
2. Definition of the scenarios to be analysed (scopes, time horizons and request intensity).
3. Identification of time and place necessities.
4. Choice of measures to be taken.
5. Programming of these measures.

In order to be **efficient**, the process of infrastructure planning for water sanitation and sewage treatment systems has to be based on the detection of necessities in different scenarios as well as on the design of measures that guarantee the successful matching of those necessities. Oversizing infrastructures is a measure that carries a better guarantee in case of higher demand in the future, but it also increases the original construction costs as well as exploitation and maintenance expenses.

The process of increasing the efficiency of investment planning in the Community of Madrid has brought with it the opportunity to reconsider the calculation of urban sewage flows and to achieve more precise calculations for a more adequate sizing of sanitation systems and sewage treatment plants in towns and cities.

The objective of this new proposal is to contribute to more efficiency when planning the investment necessities in water sanitation and treatment systems through a new method of establishing urban sewage flows.

In order to achieve this goal, a method that can be applied to both present and future scenarios by means of a parameterization according to the existing usages and properties of each case (typology) has been developed, as well as to the planned usages of future developments.

The flows that determine the future sizes of water sanitation and sewage treatment infrastructures are naturally very much influenced by the rainwater drainage flows. Indeed, it is usually said that rainwater flows determine the size of sedimentation tanks, while urban sewage flows determine the size of biological reactors. The scope of this study is limited to the calculation of urban sewage flows, but it must be borne in mind that, when designing the different components of water sanitation networks and sewage treatment plants, other flows might contribute to the establishment of the global flow.

2.2. METHOD AND SCOPE

Up until the present day, the sizing of water sanitation and sewage treatment infrastructures, as far as urban sewage flow is concerned, has been based on the calculation of these flows as a constant proportion of 80% of the designed supply flow.

This study began as a result of questioning the suitability of the present traditional criterion. In order to confirm the validity of the adjustment based on this criterion (sewage flow equals 80% of the supply flow), an analysis of the real proportions between the supplied flows and the corresponding sewage flows in the Community of Madrid was carried out.

Once it had been confirmed the discrepancies arising from using that proportion, trying to define a new criterion for calculating flow flows was started based on the consideration of different return rates for each type of water usage. Therefore, a series of return rates was defined, trying to establish the most precise values possible, taken from previous reports and others Research, Development and Innovation studies carried out by Canal de Isabel II Gestión.

After having defined the new criterion, it was worked towards its validation through a method that was similar to the one used when discussing the adequacy of the traditional criterion. The new criterion was applied to calculate urban sewage flows of the distribution systems of the Community of Madrid in scenarios where flow measurements were available. The calculation was carried out by applying the individualized return rates to the actually measured consumption figures, as well as to other non-registered usages (estimated by means of the best procedures available). These results were then compared to the figures of real measurements in the corresponding water sanitation and sewage treatment systems. The final result of applying the new criterion was much more accurate than the one achieved through the traditional criterion, so that next step was to proceed to develop a useful calculation method based on the new criterion.

The formulation of the criterion to be applied to the calculation of sewage flows for the design and sizing of infrastructures was defined according to the calculation of supply flows for design purposes. Therefore, the return rates that could be applied to the series of supply design unitary consumptions used when sizing hydraulic drinking water facilities had to be specified. These return rates had to differentiate between domestic usage (distinguishing between single-housing and multi-housing) and industrial, institutional and tertiary usage as well as usage for parks, while at the same time taking into account whether the areas in question were already developed or would be developed in the future planning.

The scope of this study finishes with a calculation of the impact that the adoption of this new criterion would have on the practical work in the Community of Madrid. Under the conviction that it is important to take into account the long-term horizon, the results obtained by using the proposed new calculation method are compared to those of the traditional method.

2.3. WHAT HAPPENS NOW AND WHAT MAY HAPPEN IN THE FUTURE

In order to understand the contents of this Research, Development & Innovation document, it is necessary to distinguish clearly between the concepts of real scenarios and hypothetical scenarios for design purposes.

The **real scenarios** and their measurements available for this study are a reflection of what has really happened in the monitored time period. They represent real factual events that help us to establish proportions and "feasible" relationships. These measurements of what has really taken place form a group of data that reflects conditions that could happen, since they have really been registered, but they do not show everything that could have happened in the past, and can in no way show everything that could happen in the future.

The **design scenarios**, as they are conceived in the sizing of civil works infrastructures, include the conditions, demands and loads the works might face during the time they are expected to function. The "maximum demand" that has to be taken into account refers to the required guarantee of service which must be defined in each case by the standardization and planning teams. By definition, the design scenarios are very likely to be more demanding than the real scenarios.

In the sector of urban waters, the calculations of demand are normally based on the concepts of "water design unitary consumptions", number of units, and to what extent these demands are simultaneous. That means that a calculation scenario is created with the defined existing or planned consumption units, the water design unitary consumption of each unit according to type of usage, and a simultaneity rate of usages for these points of consumption.

For the preparation of this study in the series of Research & Development & Innovation Booklets, these real scenarios have been taken into account both for the detection of opportunities for improvement and for the validation of the proposed new criterion. On the other hand, the design scenarios have been used for the formulation of the proposal for the new criterion and for the evaluation of the significance of the criterion change, by means of design simulations of a certain number of sewage treatment plants in the Community of Madrid.

2.4. DESIGN FACTOR OF SAFETY

During the design process of any infrastructure, a design factor of safety has to be considered, either explicitly or implicitly, in order to guarantee the response to the requests it will have to satisfy.

The calculation method based on the new criterion proposed by this document, due to its definition according to the supply, assumes the existence of design factors of safety with regard to the supply, which for their part are based on the design unitary consumptions.

3. Background and verification of the suitability of the traditional criterion

Background and verification of the suitability of the traditional criterion

For many years the simplified formula published in *Instrucción de Planificación Hidrológica*[1] was used to calculate urban sewage flows for design purposes. This traditional criterion, due to a lack of real data, is based on a direct constant proportion between the supplied water and the water returned to the sewer system:

$$Q_{daily\_sanitation\_flow\_design} = 0.8 \bullet Q_{daily\_supply\_flow\_design}$$

This calculation criterion was also adopted by Canal de Isabel II, as was published in *Normas para Redes de Saneamiento* in its 2006 version[2] (still in force), with the same return rate being used in the calculation formula for average sewage flows of domestic and industrial origin (pp. 96/97).

The European Council Directive 91/271/EEC on urban waste-water treatment only mentions that the sewer system and sewage treatment plants should be executed with the best technical knowledge and without producing excessive costs, especially regarding the following issues:

- Flow and characteristics of urban sewage
- Leak prevention
- Restriction due to recipient water contamination because of storm water overflow

On the other hand, there is a North American regulation (*Recommended Standards for Wastewater Facilities*[3]) for those facilities that are designed according to the urban sewage flow, applied in various states and provinces such as Illinois, New York, Indiana, Ohio, Ontario, Michigan, Pennsylvania, Minnesota, Wisconsin and Missouri, which proposes a calculation according to different contribution amounts to the network, depending on the water usage in each case. This regulation distinguishes between sewage design, unitary consumptions of domestic and industrial usage, without considering any other ones.

The more than evident differences in the urban configurations within the Community of Madrid, from the “week-end” developments in the mountains of Guadarrama to the high-density populations in certain suburbs of the capital city, give rise to reasonable doubts about the suitability of adopting one single criterion for calculating all sewage flows.

The company Canal de Isabel II Gestión has available a large amount of precise data from the Community of Madrid which has led to the gathering of very useful information on the water flows flowing through different strategic points of the different service networks. This availability is the result of carrying out innovation projects in the realm of planning and operating water supply, sanitation and sewage treatment systems. Among the outstanding projects in this sense are the sectorization of the supply network, the study of home consumption microcomponents, the individual consumption monitor panel, and the corporate remote control system and corporate geographic information system.

[1] *Instrucción de Planificación Hidrológica* (Hydrologic Planning Instructions), Ministerio de Medio Ambiente, Medio Rural y Marino (Spanish Ministry of Environment, Agriculture and Fishery, 2008).

[2] *Normas para Redes de Saneamiento* (Sanitation Network Regulation), Canal de Isabel II (2006).

[3] *Recommended Standards for Wastewater Facilities*, 2004 edition Wastewater Committee of the Great Lakes Upper Mississippi River.

Taking into account this background as well as the objective of improving the planning efficiency of water sanitation and sewage treatment infrastructures, it was decided to tackle the project described in this document, within the company Canal de Isabel II Gestión's sphere of responsibility.

3.1. CONTEXT ANALYSIS OF WATER SUPPLY / TREATMENT OF SEWAGE

Based on the data available for this study, it was able to work with the relation between urban drinking water supply flows and generated urban sewage flows in corresponding areas. As mentioned before, traditionally a ratio of 80% between the two was accepted as valid. However, this percentage was probably influenced by calculations used to analyse entire drainage basins, and not just urban areas in particular. In this case, it is been tried to establish a real relation between the supply systems and the sanitation and sewage systems in known urban areas, according to each case.

The Canal de Isabel II Gestión's supply system is made up of 693 sectors, with measurements being available in 343 isolated sectors for the summer season of 2012. Reliability level "7" (maximum) can be applied to 208 of these (see Appendix 1. *Data Available for This Study*).

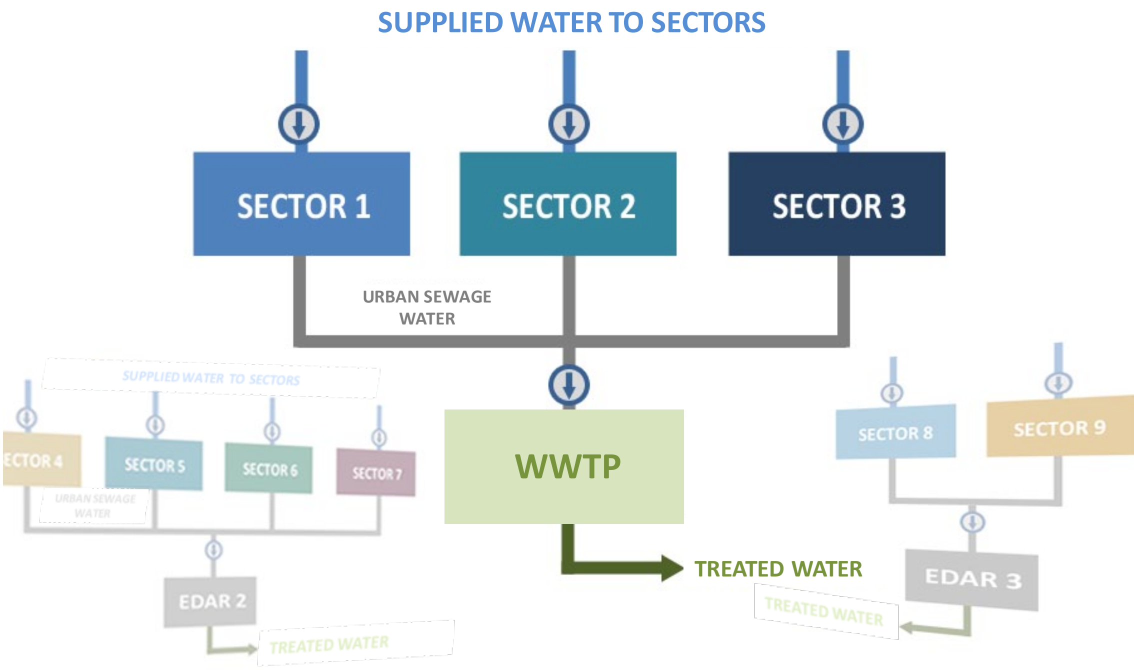
The first step within this study was to confirm the existing present relation between the supplied flows (measured at sector entrances) and the flows received at the sewage treatment plants, coming from the corresponding sectors.

The figure 5 shows a diagram of the hydraulic dependency relation between sectors and sewage treatment plants.

For each sewage treatment plant (WWTP 1, in the figure 5) the relation between the total amount of water supplied to the corresponding supply sectors (**1 + 2 + 3**) and the total sewage flow flowing back through the system was checked. Depending on data availability, the verification was carried out with real sewage data. The aim was to examine and question the suitability of the 80% relation between supply and sewage flows.

$$\frac{\boldsymbol{Water\ WWTP1\ entrance}}{\boldsymbol{Total\ water\ supply\ sectores\ 1,2\ y\ 3}} = \%\ \boldsymbol{sewage/supply}$$

FIGURE 5. **RELATION BETWEEN SECTORS AND SEWAGE TREATMENT PLANTS**



This study dealt with a total of 147 sewage treatment plants with controlled flows, corresponding to 147 different drainage basins with various reliability levels for the flow measurement.

The sector groups that correspond to the urban sewage flow at the entrance of each sewage treatment plant (WWTP, or EDAR in Spanish) were defined according to the corporate geographic information system's tools. The reliability of the analysis is based on the simultaneous reliability of the two information sources.

For the comparison of the sectors' supply flows and the corresponding WWTP's flows, the following considerations were taken into account:

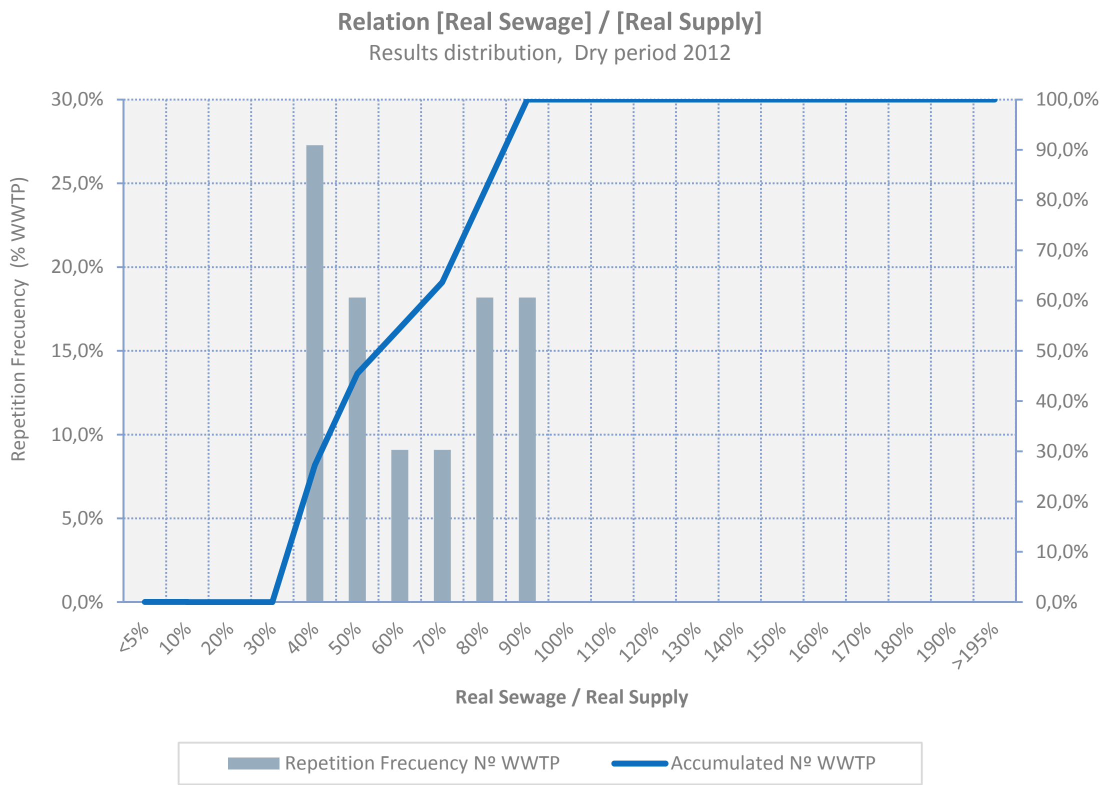
- Some of the water usages on urban ground do not generate waste water that enters the sewers.
- Some of the sewer system waters get lost on their way through the sanitation network and do not reach the WWTP.

As it will be explained in the commentaries on data reliability (see Appendix 1. *Data Available for This Study*), for the comparison between **measured supply flows** and **measured sewage flows** it was avoided using data from rainy seasons, because at those times the rainwater increases the water flow in the sewer system and affects the analysis. For this reason, the analysed period is limited to the summer of 2012.

For each WWTP, the analysis establishes the percentage of supplied water that really returns to the sewer system. According to available real values, in 82% of the cases the returned flow did not reach 80% of the supplied flow, and in 60% of the cases the returned flow was even lower than 70% of the sectors' supply.

The figure 6 shows the percentage of sewage treatment flow with regard to the total supply flow of the sectors with treated waste water, for the WWTPs with maximum combined reliability (Group 1, containing 11 WWTPs; see Appendix 1. *Data Available for this Study*).

FIGURE 6. FREQUENCY DISTRIBUTION OF THE RELATION BETWEEN REAL SEWAGE FLOW AT WWTP AND REAL SUPPLY FLOW. MAXIMUM RELIABILITY

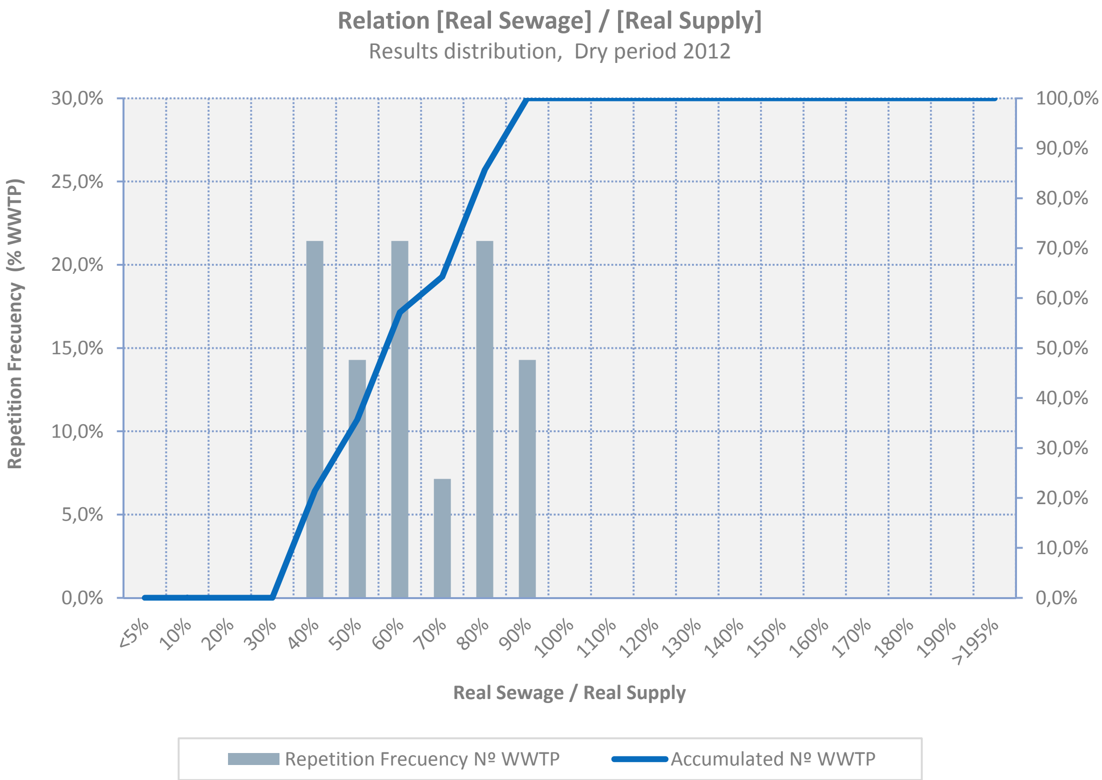


The figure 7 shows a diagram for a combination of slightly less reliability (Group 2; see Appendix 1. *Data Available for This Study*); in this case, the analysis includes 14 WWTPs and shows similar variability to the earlier one.

In any case, the proportionality between the real sewage flow and the real supply flow was not a constant one.

Both analyses clearly show the existing variability of the ratio between the supply flows and the sanitation and sewage treatment flows (from 40% to 90%), in spite of the compensation factor which undoubtedly exists due to adding sectors of different compositions and characteristics.

FIGURE 7. **FREQUENCY DISTRIBUTION OF THE RELATION BETWEEN REAL SEWAGE FLOW AT WWTP AND REAL SUPPLY FLOW. HIGH RELIABILITY**



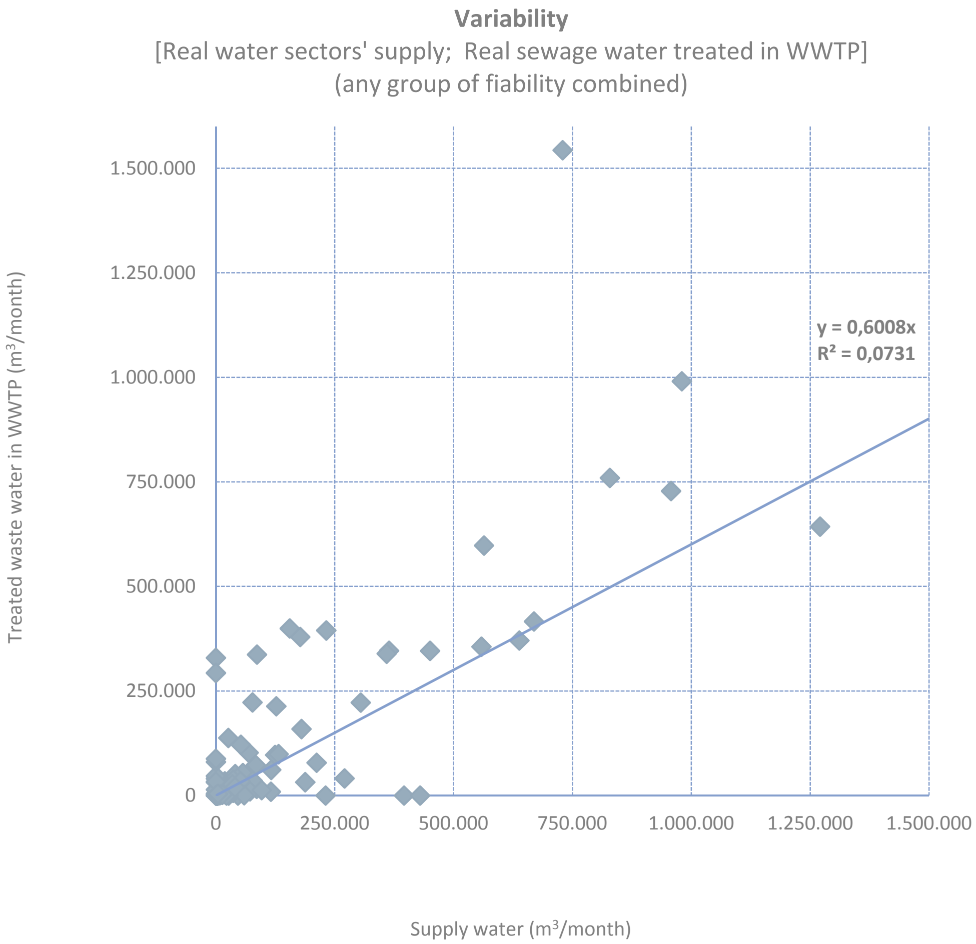
This proven variability is just one more reason for trying to find a calculation criterion for sanitation flows which can take into account the various characteristics of different water usages in each town and area, as well as various states of sanitation infrastructures.

3.2. RELATIONSHIP BETWEEN THE FLOW'S MEASUREMENT OF WATER SUPPLIED AND THAT OF THE TREATED WASTE WATER ACCORDING TO DIFFERENT RELIABILITY FILTERS

An analysis was undertaken of the relation between sewage and supply for all of the available data of all the sewage treatment plants with their different reliability levels.

The relation between the measured supply flows at the sectors' entrances and the measured sewage flows at the corresponding WWTPs leads to the diagram shown in the figure 8. Once again, the lack of consistency as to the constant percentage ratio is obvious.

FIGURE 8. **VARIABILITY OF RELATION BETWEEN REAL SUPPLY FLOW TO SECTORS AND REAL SEWAGE FLOW AT WWTPS**

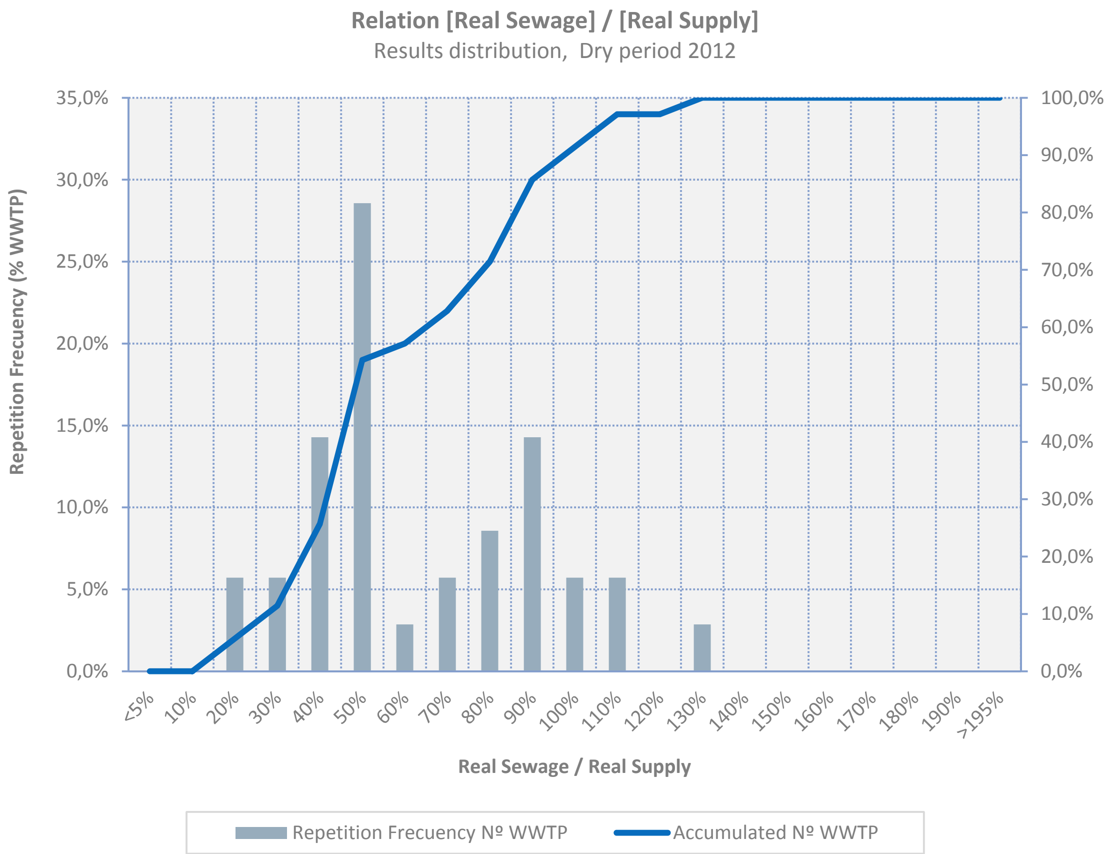


The resulting variability was analysed organizing the various percentage ratios of the relation **"measured sewage flow/measured supply flow"** into groups.

The results can be seen in the figures 9 and 10, organizing the WWTPs in groups according to their reliability, completing the two combinations shown above.

The figure 9 shows the sewage treatment plants of medium reliability (Group 3, 35 WWTPs; see in Appendix 1. *Data Available for This Study*).

FIGURE 9. FREQUENCY DISTRIBUTION OF THE RELATION BETWEEN REAL SEWAGE FLOW AT WWTP AND REAL SUPPLY FLOW. MEDIUM RELIABILITY

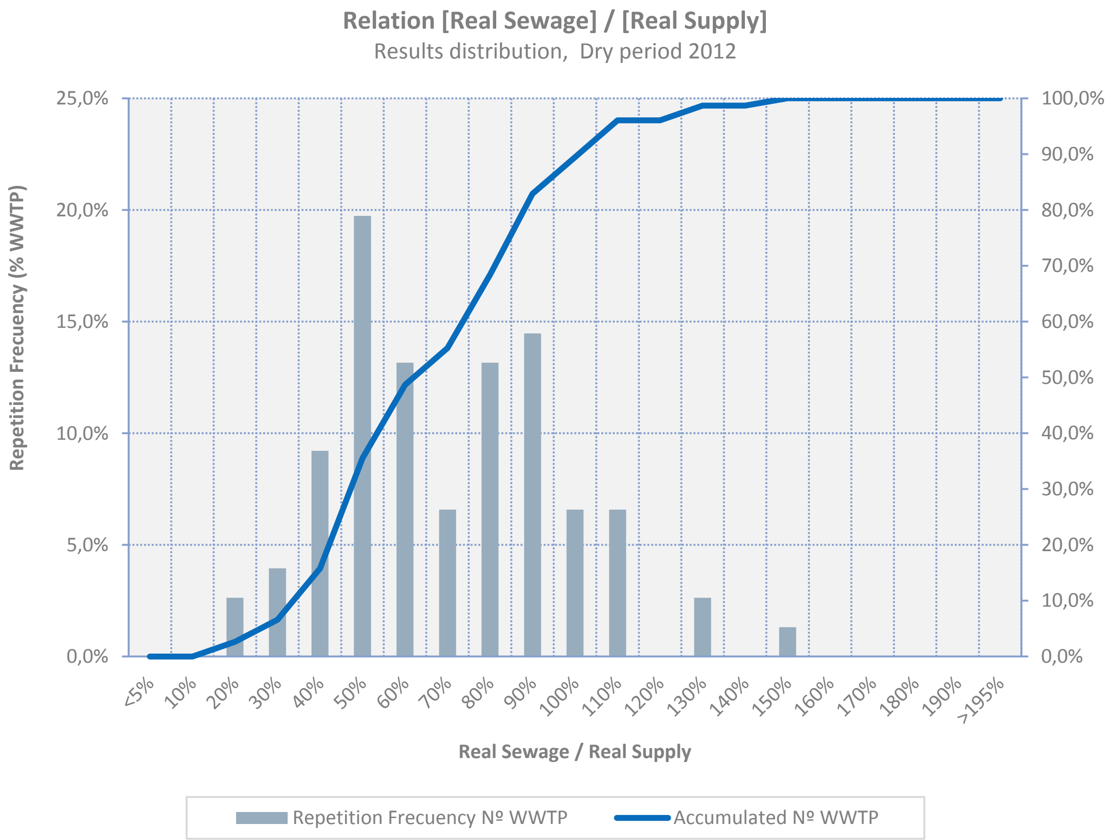


This last analysis includes all sewage treatment plants that provide service groups of sectors with a very high reliability regarding the supply flow measurements. In this case, a discontinuity can be observed in the frequency curve, showing a point of inflexion at "up to 50%" (of proportion between sewage flow and supply flow).

In addition, a group of frequencies for the sewage flow /supply flow ratio appears with a maximum of 90%. It should also be pointed out that there are sewage flow measurements that are higher than the drinking water supply flows in the areas serviced by the WWTP: obviously, these waste water treatment plants cannot be used for the validation analysis in this study because they might refer to data or measurement errors, to mistakes in the configuration of usages and sectors, or to water intrusions in the sanitation network.

Finally, the figure 10 shows the sewage treatment plants of reliability Group 4 (76 WWTPs; Appendix 1. *Data Available for this Study*).

FIGURE 10. **FREQUENCY DISTRIBUTION OF THE RELATION BETWEEN REAL SEWAGE FLOW AT WWTP AND REAL SUPPLY FLOW. WITHOUT RELIABILITY FILTERS**



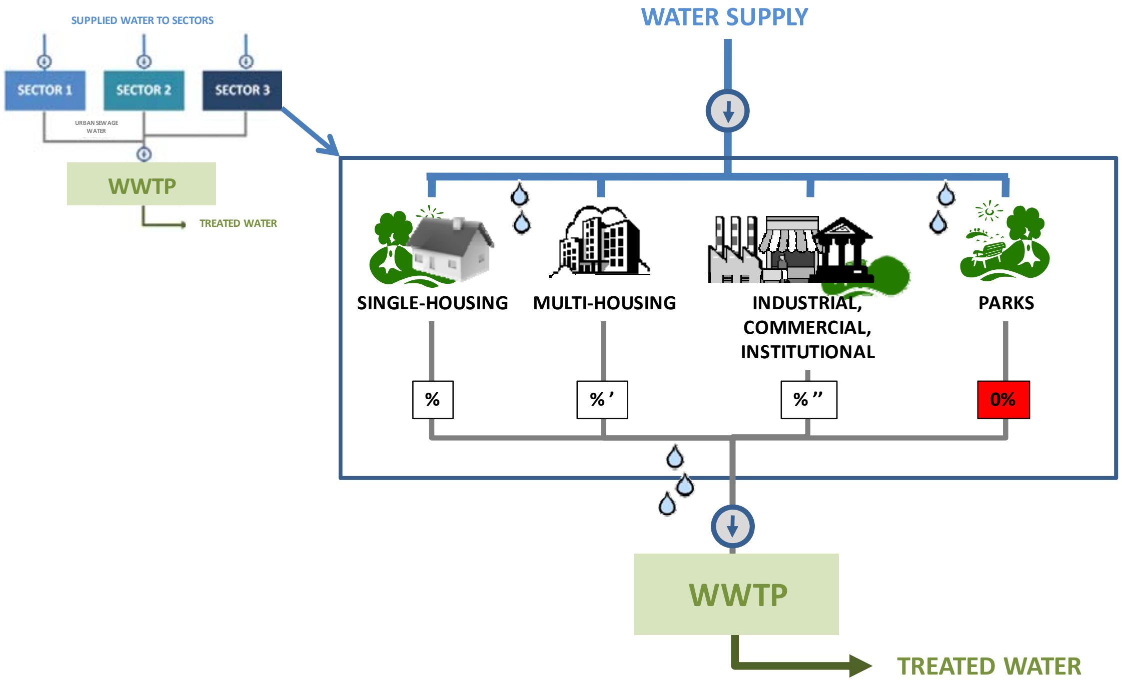
By introducing all the available cases (with any assigned reliability), the “double bell effect” seen in the earlier figure is softened.

4. Proposal of an alternative criterion

The proposed new criterion for calculating urban sewage flow is based on the distinction and standardization of the supply water usages. The proposal uses the flow calculations in dry periods for design purposes of water sanitation and sewage treatment networks.

The new criterion distinguishes between two components in each usage of the supplied water: a "**consumption**" aspect and a "**poured into sewer**" component. This means that each supply water usage goes with a different percentage of poured water (see the figure 11), so that each sectors generated urban sewage flow depends on the usage that is really applied to the supplied water.

FIGURE 11. SEWAGE PERCENTAGE ACCORDING TO WATER USAGE



In order to find a new method of calculation, the knowledge and experience of designing supply systems was used. For supply systems, the flow is calculated by adding standardized individual consumptions with their corresponding design unitary consumptions. In a similar way, one can carry out the calculation of urban sewage flows by taking into account the individual properties with their design unitary consumptions and specific return rates. This would mean abandoning the concept of one single constant return rate for entire consumption areas or regions.

The properties are classified according to the type of usage applied to the drinking water, which determines the proportion of water that returns to the sewer system. This means that each type of property has its own specific "return rate". The establishment of the numerical value of each return rate is based on the conclusions of the study on microcomponents and final usages carried out in 2008 by Canal de Isabel II in the Community of Madrid, as well as other relevant studies. The microcomponents (and final usages) of drinking water refer to each one of the purposes the water is used for within a property.

This means that the new criterion is based on the individual considerations on the "properties" that generate the sewage water. "Property" refers to the physical unit that consumes water or, in this case, that returns water to the sewer system. In the context of housing, a property would be each one of the apartments in a multi-housing building, or each one of the houses or cottages inhabited by a single family. For other non-domestic usages, property refers to a natural unit of water consumption or generation. In the case of the Community of Madrid and its regulations for contracting a water service, a non-domestic property means one service contract: one property for each business space, one property for each company, one property for each institutional public usage water outlet, one property for each irrigation system in parks or on roads, etc.

In the context of domestic usage, the microcomponents distinguish between water destined for such purposes as showers, washing machines, dish washers, taps, lavatories, as well as for exterior usage such as patios and gardens. Based on the knowledge of the proportions of each one of these final usages, one establishes the percentage of supplied water that is returned from the housing units to the sewer system, distinguishing between the return rates of multi-housing and single-housing buildings.

As to the other usages, the establishing procedure is similar. A special case is the exterior usage of water in parks and public and private gardens, where the return rate to the sewer system is assumed to be nil.

In order to establish the return rate of other usages and purposes of water that really take place or occur in urban areas, the intention of the new criterion to represent the percentage of water that finally flows through the sewer system has been taken directly into account. These "other usages" had a certain importance as they dealt with the most precise verification possible of this process, including water usages such as pipe drains, pipe cleaning, fraudulent usage, etc.

5. Verification of the validity of the new criterion

In order to validate the proposed new criterion as a calculation method, it was checked the accuracy of the adjustment of the real measurement data of urban flows against the values achieved by applying the specific return rates of different drinking water usages (adjusted to the real values) according to the measurements in the individual properties. In this way, the real consumption flow of drinking water measured at the users' properties was converted into calculated flows of sewage water. Afterwards, it was checked whether this calculated sewage flow matches the real sewage stream flowing through the sewer systems to the sewage treatment plants of Canal de Isabel II Gestión.

In this way a "calibration scenario" was defined that established all the destined uses of the water supplied to each one of the supply sectors that are useful for this analysis. For this purpose the database of registered individual consumption measurements by the users' meters was used, classifying them by type of usage. The flows supplied to the distribution networks in each sector which do not correspond to the users' measured consumption (uncontrolled water) were obtained by the same calculation and calculation methods that are applied in order to establish the different efficiency indicators for the distribution sectors.

During this entire process a matrix was used to assign the drinking water consumption areas (supply sectors) and sewer systems (sewage treatment plants' drainage basins). The measured data had necessarily to be classified by their level of reliability, taking into account not only the assumed data quality, but also their representativeness and their reliability for the purposes. As mentioned before (chapter 3, "*Background and verification of the suitability of the traditional criterion*"), only data series from dry periods in 2012 were used.

Finally, the return rates for the different types of present usage were established as follows:

- Domestic usage in multi-housing buildings: 1.00
- Domestic usage in single-housing buildings: 0.73
- Industrial, institutional and tertiary usage: 0.90
- Exterior usage (irrigation): 0.00

What follows is a detailed justification of the rates that have been used in the specific formulation for the proposal's calibration.

5.1. VALIDATION OF THE PROPOSED CRITERION FOR DEVELOPED URBAN GROUND

The validation was carried out by confirming the proposed criterion's capacity to reproduce the existing flows at the entrance of the sewage treatment plants within the scope of this study by means of calculation.

In order to achieve this, the different return rates were applied to the corresponding real measured consumption values at each individual property in the drainage basins of each WWTP. The total results after adding the different individual flows were then compared to the real flows that were measured at the entrances of the WWTPs.

The figure 12 shows graphically how the data used in the validation formula were selected:

∑ (individual_returns) i ≈ measurement_entrance_WWTP i

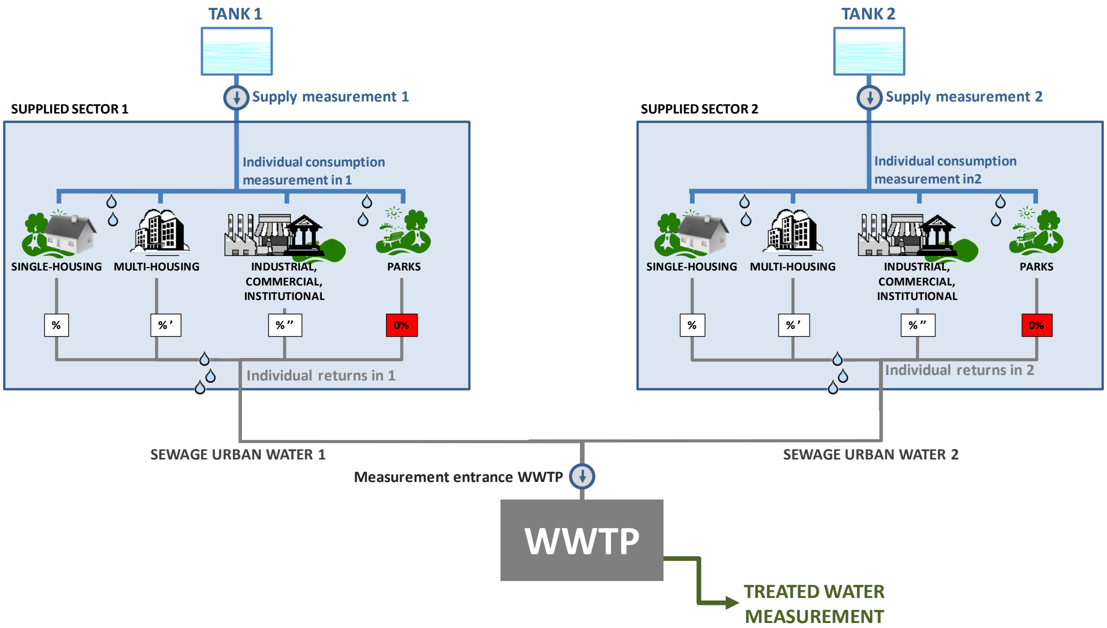
Total return flows to sanitation ≈ measured flow at WWTP entrance

where

∑ (individual_returns) i = ∑ (return_rates x measurement_individual_consumptions) i

Total return flows to sanitation = Total of each user's measured flow multiplied by their return rate

FIGURE 12. WORK DIAGRAM FOR THE PROPOSED CRITERION'S VALIDATION



5.1.1. Application of the new criterion to present circumstances

This section justifies and explains the use of the formulation's return rates applied to real measurement data from sectors and WWTPs.

- Multi-housing usage

In multi-apartment buildings with domestic usage, the sewage flow generated is considered to be **100%** of the actually measured supply flow for **multi-housing domestic use** in the areas analysed by this study.

This flow was increased to compensate calculated under-metering.

- Single-housing usage

The **single-housing domestic usage** was calculated to be **73%** of the actually measured supply flow for each of the study's areas.

The **27%** difference between the two values corresponds to **exterior usages** which are typical for this type of housing, according to data found in the study "***Microcomponentes y factores explicativos del consumo doméstico de agua en la Comunidad de Madrid***"[4], the number four in the series *Booklets of Research, Development and Innovation*. The appropriateness of the application of this percentage has been confirmed through the domestic consumers monitor panel that was active in 2012.

This flow was increased to compensate calculated under-metering.

- Industrial usage

The **industrial usage** was calculated to be **90%** of the actually measured supply flow for each of the study's areas.

It was assumed that **100%** of the industries make a "non-consuming" usage of the supplied water, meaning that they return the entire amount of received water to the sanitation system.

This flow was increased to compensate calculated under-metering.

- Commercial usage

The **commercial usage** was calculated to be **90%** of the actually measured supply flow for each of the study's areas.

This flow was increased to compensate calculated under-metering.

- Institutional usage

The **institutional usage** was calculated to be **90%** of the actually measured supply flow for each of the study's areas. In this usage category the water used for irrigation was not included, in particular in the city of Madrid (even though there are certain coincidences between institutional usage and irrigation as far as the rates are concerned).

This flow was increased to compensate calculated under-metering.

[4] *Cuadernos de I+D+i* nº. 4 *Microcomponentes y factores explicativos del consumo doméstico de agua en la Comunidad de Madrid* (Microcomponents and explanatory factors of domestic water consumption in the Community of Madrid), Canal de Isabel II, Madrid (2008).

- Estimated fraud

The fact that the cases of permanent fraud correspond to domestic usage was taken into account, which is why this portion is considered to be equal to **100%** of the estimated flow of water consumption through **fraudulent connections** in each of the study's areas.

The lack of precision in the estimation of this element makes further efforts of discrimination unnecessary. The distribution of the estimated total flow of fraudulent water consumption in the Community of Madrid was carried out proportionally to the surface of each of this study's areas.

- Pipe drains in the distribution network

This flow was calculated to equal **100%** of the estimated **pipe drains flow** in the study's areas. This calculation is based on the individualized knowledge of the drains operations in the distribution network taking into account the measurements of Canal de Isabel II Gestión's corporate event and warning system. These georeferencing operations, as well as the inclusion of temporary data and used drains elements in the register secure this method's high reliability.

- Cleaning of new pipes and facilities

This flow was calculated to equal **100%** of the calculated **cleaning flow** in the study's areas. This calculation is based on the information on works carried out during the study's duration, taking into account both newly constructed pipes and replacement of old pipes. The availability of the corresponding data in the corporate geographic information system, and the fulfilment of the technical instructions on pipe cleaning and disinfection, guarantee this calculation's reliability.

- Controlled and uncontrolled irrigation, other usage and existing leaks

For the rest of supply water usages a proportion of **0%** of the measured or calculated flow was assigned. Thus, supply water being used in a way that keeps it from being reintroduced to the sewer system is not considered in the calculation of sewage flows.

Taking into account that real consumption is measured by reading individual meters with an inherent error, the flows of this origin (individual metering data base) were increased in each case to compensate under-metering, according to the results published in *Cuadernos I+D+i*, nº 8, *Precisión de la medida de los consumos individuales de agua en la Comunidad de Madrid* (*Precision of individual water consumption meter measurements in the Community of Madrid*).

The calculation formula is the sum of all the factors mentioned above, as shown here:

Q_sanitation =	**[Dmv·(1+S)]·number_multi-housing**	*Multi-housing buildings*
	+ [Duv·(1+S-Euv-S·Euv)]·number_single_housing	*Single-housing buildings*
	+ [Di·(1+S)]·area	*Industries on developed urban ground*
	+ [Dc·(1+S)]·area	*Businesses on developed urban ground*
	+ [Dy·(1+S)]·area	*Institutions on developed urban ground*
	+ [Fa+P+L]·area	*Estimates for fraud, drains and cleaning on developed urban ground*

The abbreviations' meanings correspond to the concepts defined in the table 2.

TABLE 2. CONCEPTS USED IN THE CALCULATION OF NEW CRITERION FORMULATION. CALIBRATION SCENARIO

Concept	*Present calibration scenario*
Domestic multi-housing usage **[Dmv]**	Real meter reading
Domestic single-housing usage **[Duv]**	Real meter reading
Domestic single-housing exterior usage **[Euv]**	**27%**
Under-metering **[S]**	**10%** (approximate, according to range and period)
Industrial usage **[Di]**	**90%** of real meter reading
Commercial usage **[Dc]**	**90%** of real meter reading
Institutional usage **[Dy]**	**90%** of real meter reading
Estimated fraud **[Fa]**	**100%** according to hydraulic balance chapter
Estimated or calculated drains **[P]**	**100%** according to hydraulic balance chapter
Estimated or calculated pipe and facility cleaning **[L]**	**100%** according to hydraulic balance chapter

5.1.2. Verification through current measurements at sewage treatment plants

In order to verify the criterion's adaptation regarding the available measurements at the sewage treatment plant, the sectors corresponding to each drainage basin were grouped together, according to the existing sanitation systems. It had to be confirmed whether it matches for each WWTP "u" with reliable readings during the analysis period.

$$\sum R^{c}_{u} \approx D_{u}$$

Where:

R^{c}_{u} Calculated sewage flow for validation of the areas corresponding to WWTP "u"

D_{u} Metered entrance flow at WWTP "u"

The proposed criterion's perfect adaptation to the diversity of consumptions, usages and sewer system states would lead to a result of the relation between calculated flow and real flow close to 100%.

The sum of the results of sector sewage flows compared to real flows measured at the WWTPs showed that 55% of the WWTPs achieved a very good adaptation (between 90% and 120%). The result values that occurred most frequently were 60% and 120%.

The verification is shown in the figure 13 which includes the 11 WWTPs with the combination of highest reliability (Group 1, 11 sewage treatment plants; see Appendix 1. *Data available for this study*).

Within Group 2 of a slightly lower reliability with 14 plants, the resulting variability was similar, except regarding the highest relation values. Once again, the highest frequency could be observed at **60%** and **120%**, as shown in the figure 14.

FIGURE 13. VERIFICATION OF THE NEW CRITERION'S APPLICABILITY FOR MAXIMUM RELIABILITY MEASUREMENTS

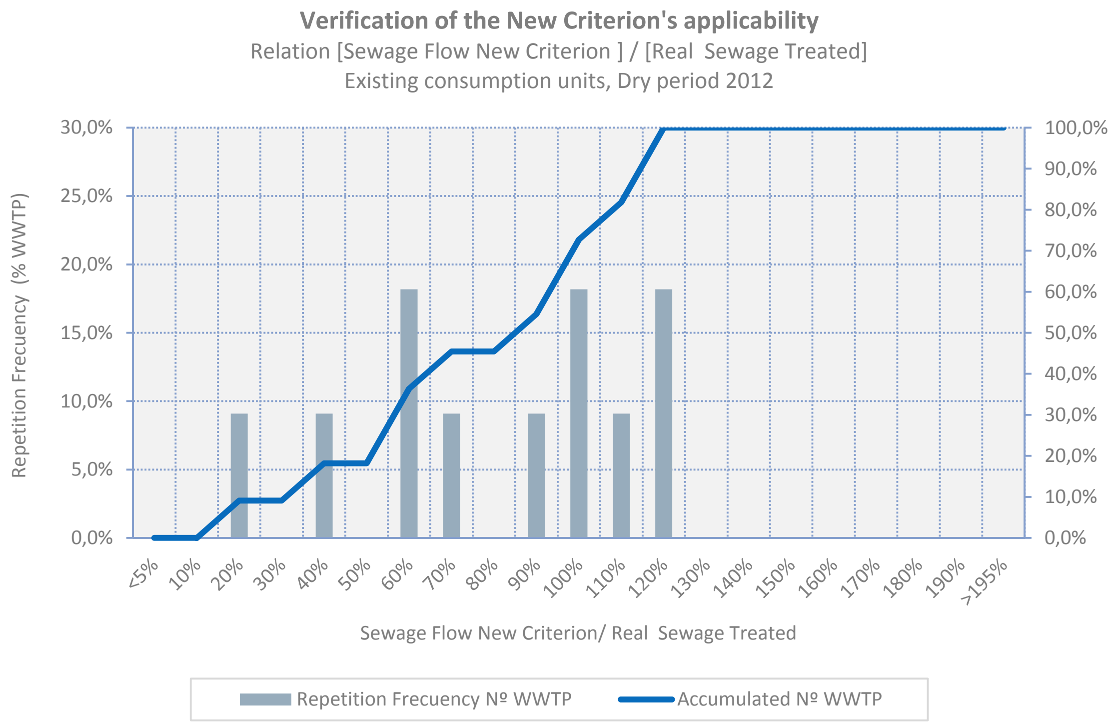
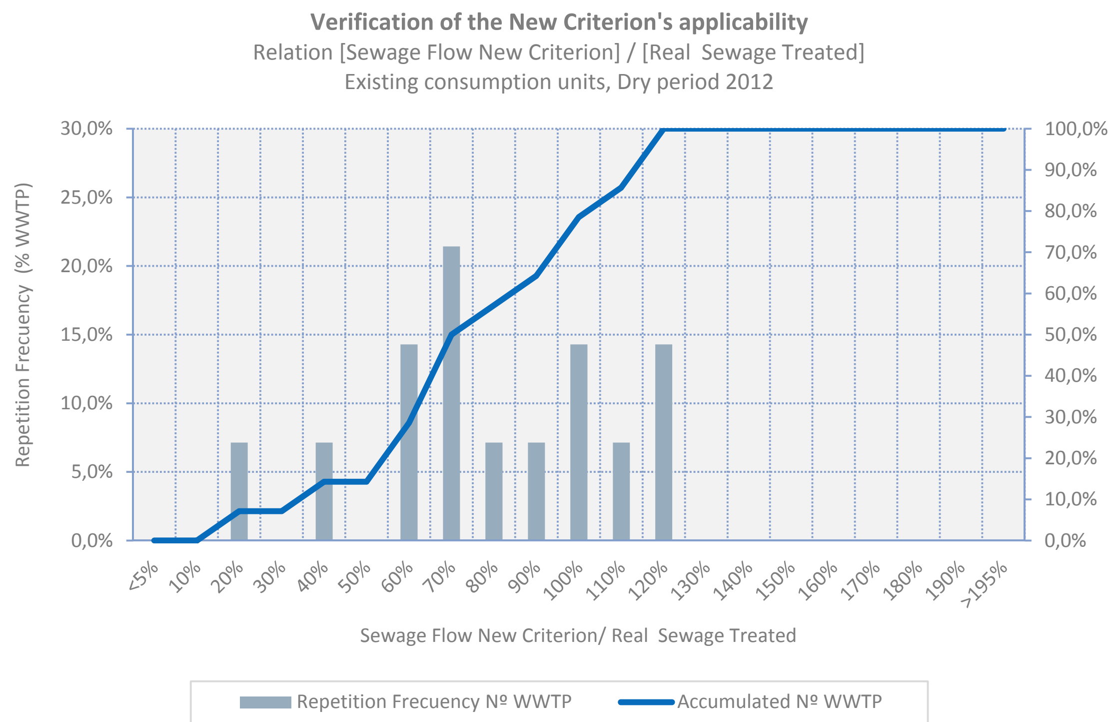


FIGURE 14. VERIFICATION OF THE NEW CRITERION'S APPLICABILITY FOR HIGH RELIABILITY MEASUREMENTS



5.1.3. Evaluation of the criterion in isolated supply sectors

It was thought a further confirmation would be appropriate comparing the sewage flow calculation carried out with the new criterion, with the sectors of controlled supply. The aim of this confirmation is to analyse the resulting proportion between the calculated urban sewage flow and the real measurements of the supply flows at each sectors' head. Just as with the other aspects of this document, the data used for this confirmation are from summer 2012. The group of selected sectors for this analysis belongs to those with high reliability.

In every one of these cases, a calculated sewage flow smaller than the supplied drinking water flow was expected.

Expressed mathematically, this is:

$$\mathbf{R^{c}_{i} < A_{i}}$$

All supply flows for sector "i" are considered to be reliable during the analysed period.

Where:

$\mathbf{R^{c}_{i}}$ urban sewage flow for validation, calculated in sector "i"

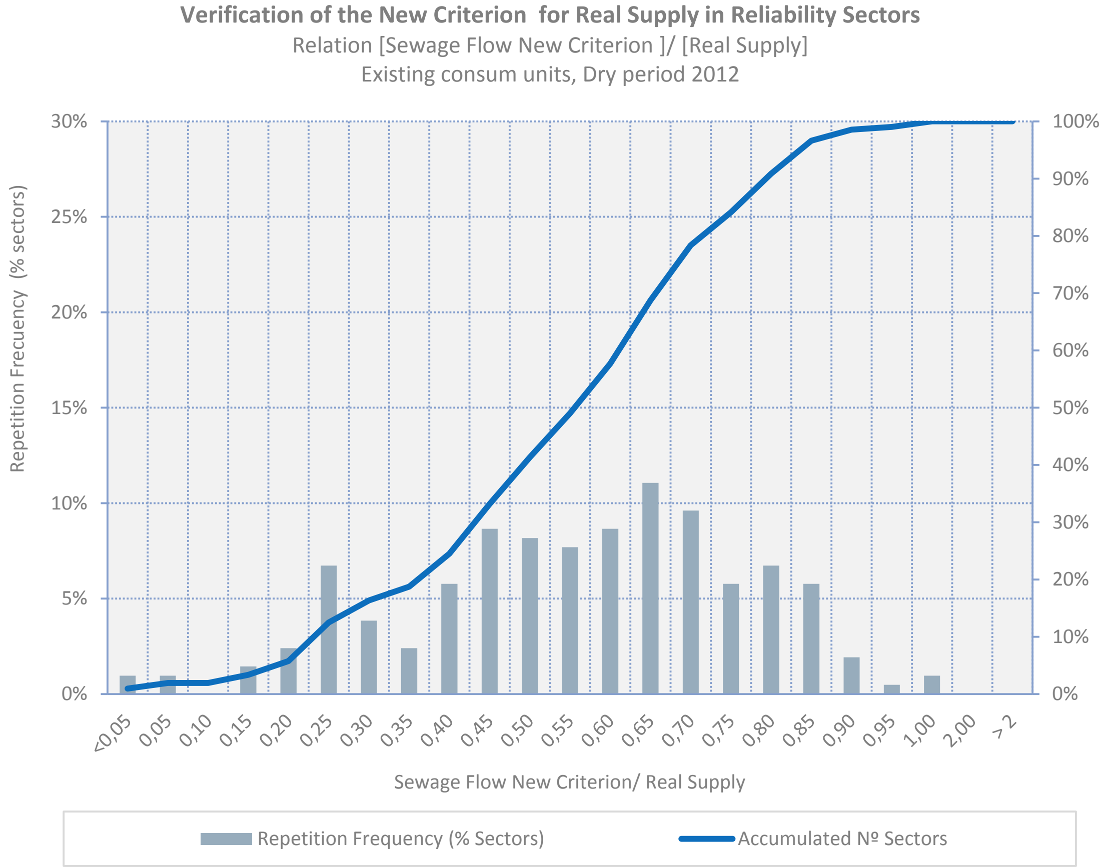
$\mathbf{A_{i}}$ supply flow in sector "i"

This led to a result of 80% of the sectors reaching a relation between calculated sewage flow with the proposed criterion and really measured supply flow of less than 0.80. The most frequent value turned out to be 0.65.

The figure 15 shows the obtained relation between calculated sewage flow with the proposed criterion and really measured supply flow for the 208 sectors with the highest reliability.

The resulting variation is larger than the one achieved by the analysis of sewage treatment plants, not only because the number of analysed cases was higher this time, but also because of the compensation factor that the sectors have on one another by being organized in larger groups (drainage and sewage treatment basins).

FIGURE 15. VERIFICATION OF THE NEW CRITERION FOR MAXIMUM RELIABILITY SECTORS



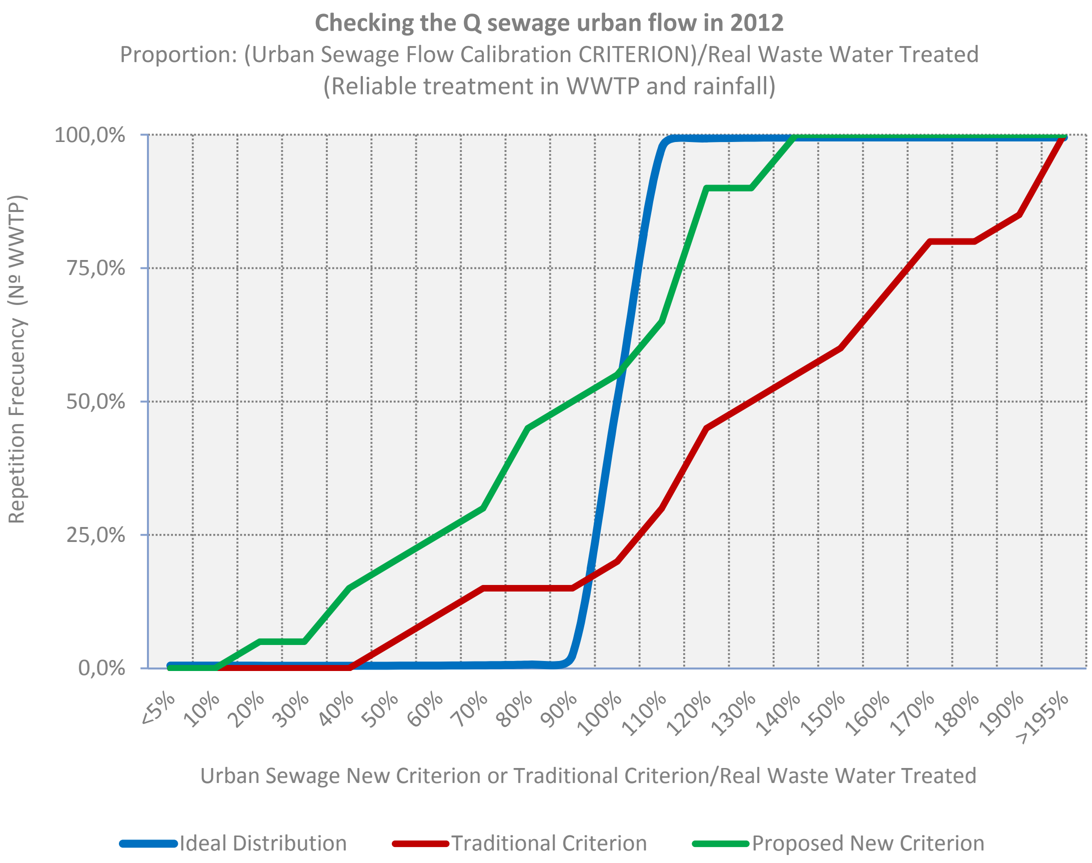
5.2. COMPARISON OF THE RESULTS' ADJUSTMENT OBTAINED WITH THE PROPOSED NEW CRITERION AND WITH THE TRADITIONAL ONE

In order to find out whether the calculations carried out with the "**proposed new criterion**", adapted for calibration by the means of real data, show a better adjustment than those made with the "**traditional constant criterion**", both adjustments were simultaneously compared with the measurements of sewage streams that really flow through the sewer systems.

The results showed a better adjustment for the urban sewage flow calculation method that uses the new criterion.

This analysis is shown graphically by the accumulated frequency curve for sewage treatment plants achieved in each one of the adjustment intervals (percentage of calculated flow compared to real flow): see the figure 16. The blue curve is a graphic reference that represents an ideal distribution, meaning that the sewage flow matches the flow of treated water in all the analysed cases.

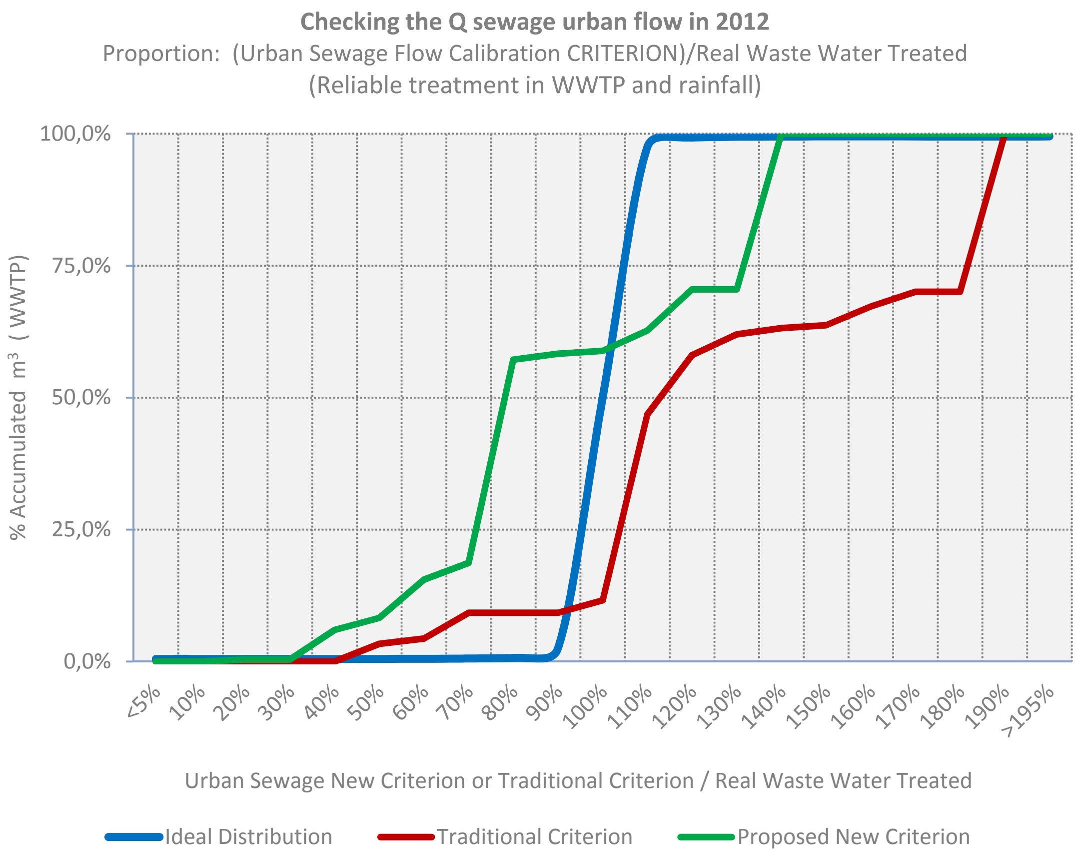
FIGURE 16. COMPARISON OF PROPOSED NEW CRITERION VS. TRADITIONAL CRITERION. WWTP



Similarly, an adjustment analysis was undertaken by evaluating what calculated and real sewage flows were being treated during different intervals, adding the flows on a daily basis, instead of by counting the numbers of each level's sewage treatment plants.

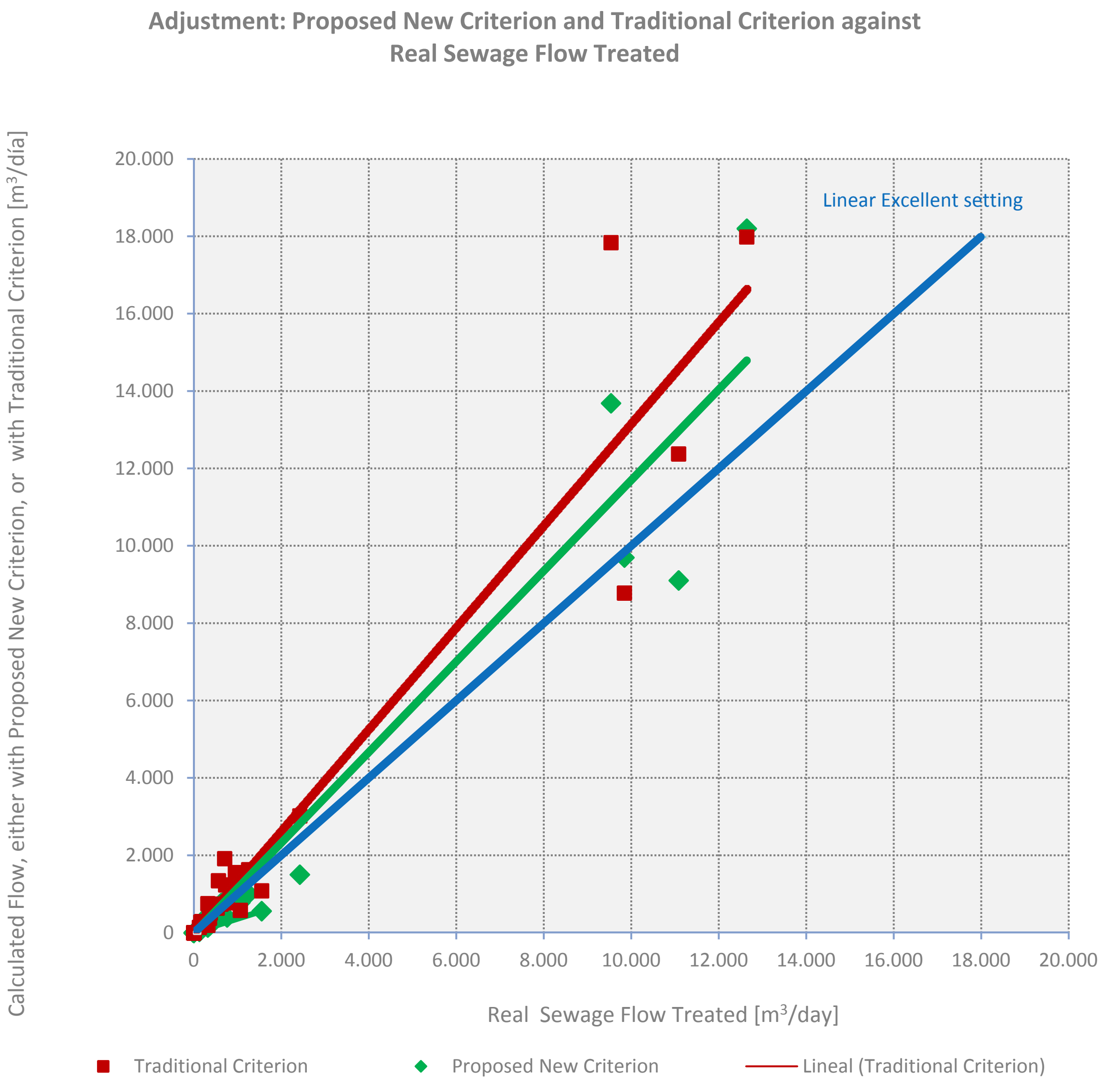
The following representation of the results confirmed the aforementioned improvement achieved by applying the new criterion. The figure 17 shows clearly that the proposed new criterion's curve is closer to the "ideal curve" than that of the traditional criterion.

FIGURE 17. **COMPARISON OF PROPOSED NEW CRITERION VS. TRADITIONAL CRITERION. URBAN SEWAGE FLOW IN WEIGHTED M^3**



To show more clearly the significance of the improvement brought about by the new criterion, the variability diagram in the figure 18 includes the urban sewage flow calculations according to both criteria, in comparison to the sewage flow really treated by each WWTP. Once again, it is obvious that the new criterion achieves a better adjustment to the ideal proportion between really treated sewage flow and calculated sewage flow for validation, than the traditional one.

FIGURE 18. **PROPOSED NEW CRITERION AND TRADITIONAL CRITERION IN COMPARISON TO REAL SEWAGE FLOW**



These analyses led to the conclusion that the definition of this new criterion for calculating sewage flows is certainly a step in the right direction, while, at the same time it shows that there is still room for improvement.

6. Formulation of the new criterion for calculating sewage flows for design purposes

Formulation of the new criterion for calculating sewage flows for design purposes

After having confirmed the greater validity of the described new criterion's adaptation to the variation in water usage, it was tried to find an adequate formulation for calculating urban sewage flows, for the purpose of infrastructure planning and sizing. The desired formulation was set out in relation to the variables used in planning and sizing water supply and distribution infrastructures. This means that the proposed formulation for the new criterion's application to the design of sanitation facilities is defined by the establishment of return rate values that are appropriate for each supply facility used.

It is important to point out that for design purposes, this document takes into account the calculation of the average flow on the day of maximum consumption, and does not consider peak-time consumption.

Planning, as it was said before, is based on the definition of certain work scenarios, each one with its circumstances of time and space which normally include both properties on already developed urban ground and new constructions. The division into these two categories is important because the design unitary consumption of each property affects the sizing practices for supply facilities, while at the same time these practices are taken into account for designing sanitation and sewage treatment infrastructures.

The design unitary consumptions used in this study have been calculated according to the methods and suppositions published in the report ***Proyección de demanda en la Comunidad de Madrid a los horizontes de planificación***, ***revisión 1***[5]. For calculating the daily average sanitation flows for design purposes, the flow rate on the day of maximum consumption was used, similar to the case of planning supply infrastructures.

For the purpose of planning and defining the supply infrastructures, it is taken into account the following distinction between water usages:

- Domestic usage in multi-housing buildings
- Domestic usage in single-housing buildings
- Industrial, institutional and tertiary usage
- Parks

This distinction matches the one applied in urban planning which will be used further ahead for the definition of scenarios in the future.

Each one of these drinking water usages relies on a **presently water design unitary consumption** for either previously existing properties or imminent future ones (Since they correspond to the urban soil already developed).

[5] ***Proyección de demanda en la Comunidad de Madrid a los horizontes de planificación, revisión 1*** (Demand projections for planning purposes in the Community of Madrid). Canal de Isabel II, Research, Development & Innovation unit, Madrid, December 2008.

The quantification of these design unitary consumptions relates to the results of statistical studies on real long-term consumption measured in the Community of Madrid, divided into towns for domestic usage, and into 11 larger areas for non-domestic usages. These supply design unitary consumptions represent the possible consumption at the present time, in conditions of maximum consumption for design purposes. The method described in this document identifies “return rates” that are suitable for transforming the supply design unitary consumptions into individual urban sewage flows for design purposes, both for existing properties and for imminent future properties on already developed ground.

As to calculating **urban sewage water generation on future properties**, the supply design unitary consumptions that have been defined for these future properties were used, applying the return rates that correspond to each type of usage, but modified (in relation to the present usage rates) in order to adapt them to the differences in the definitions of those design unitary consumptions. In the case of future design unitary consumptions, a deduction was applied that corresponds to leaks and other purposes which should not be included in the calculation of sewage flows, but had been taken into account when defining the supply design unitary consumptions.

Therefore the new proposal consists of introducing a new calculation method for urban sewage flows, based on different return rates for each type of usage of the supplied drinking water and for each situation, as far as consolidation or planning of future urban ground is concerned, as it can be seen in the table 3.

TABLE 3. PROPOSED RETURN RATES ACCORDING TO USAGE TYPE AND CONSOLIDATION STATUS

Concept	*Return rates for design unitary consumptions*	
	Usage on developed ground	*Usage for future planning*
Multi-housing usage	100%	95%
Single-housing usage	73%	80%
Industrial, Institutional and Tertiary usage	90%	85.5%
Other usage	0%	0%

These percentages are the result of the study carried out by the Canal de Isabel II Gestión, for a particular case, and depend both on the definition of the supply design unitary consumptions and on the components of the final destination for each type of usage. For other cases and application scopes, the corresponding return rates should be adapted accordingly.

In the following sections, the ways of establishing the indicated values for each return rate will be explained in detail.

6.1. CRITERION FOR CALCULATING SEWAGE FLOWS ON DEVELOPED URBAN GROUND FOR DESIGN PURPOSES

The daily average urban sewage flow generated in a certain area is calculated according to the usages that are to be expected for the supplied water, depending on the design unitary consumptions on each usage individually. That means that the sewage flow is made up of the water that is being returned to the sewer system by single housings, multi-housings and industries, institutions and tertiary users, according to each one's usage. In each case, a proposed specific return rate is applied, depending on the different supply design unitary consumptions.

The design unitary consumptions available for calculations within the Community of Madrid distinguish between two kinds of domestic usage (multi-housing and single-housing), on the town level. For industrial, institutional and tertiary usage, the design unitary consumptions are defined differently for a total of eleven larger socio-economic areas within the Community of Madrid. When calculating the flow of domestic design unitary consumptions, it was taken into account that many of those belong to secondary homes, which are considered to make up 50% of the difference between the homes considered by urban planning and the number of main homes registered officially by the Spanish INE (National Statistics Institute).

These supply design unitary consumptions for properties on developed urban ground were analysed by using real measurement data from June and July in a significant series of years. In order to assess the total water flow of the day of maximum consumption, this number of design unitary consumptions has to be multiplied by a “maximum day rate”. This rate depends on the total number of properties that exist within the area of study, either the local hydraulic system, the regulation reservoir, etc., and represents the rate of simultaneous demand: the larger the number of properties, the lower the maximum day rate (because the more properties there are, the more difficult it is for a simultaneous global maximum demand to occur). The formulation of the maximum day rate also depends on the analysis of real data regarding the sectors’ supply systems of the Community of Madrid.

The same procedure will be used for calculating flows for design purposes regarding the sizing of sanitation and sewage treatment systems.

6.1.1. Multi-housing usage

In the case of design unitary consumptions classified in the category of **developed urban ground for multi-housing usage**, the calculation will include **100%** of the designed supply design unitary consumptions.

These will match the design unitary consumptions in the significant area where the zone or area being considered is located. They are free of percentage compensations due to uncontrolled usage (leaks, fraud, operational usage, etc.).

6.1.2. Single-housing usage

In the case of design unitary consumptions classified in the category of **developed urban ground for single-housing usage**, the calculation will include **73%** of the designed supply design unitary consumptions of the sector studied.
These will match the design unitary consumptions in the significant area where the zone or sector being considered is located.

In this case the 27% difference corresponds to exterior usages which are typical for this type of housing, according to studies carried out by Canal de Isabel II, published in the number 4 of the series *Cuadernos I+D+i*, “*Microcomponentes y factores explicativos del consumo doméstico de agua en la Comunidad de Madrid”* (Microcomponents and explanatory factors of domestic water consumption in the Community of Madrid).

The application of this percentage turned out to be consistent with, and confirmed by, the domestic consumers monitor panel that was active in 2012.

These design unitary consumptions are also free of percentage compensations due to uncontrolled usage (leaks, fraud, operational usage, etc.).

6.1.3. Industrial, Institutional and Tertiary usage

In this case, the calculate criterion will include **90%** of the designed supply design unitary consumptions on developed urban ground of the sector studied for industrial, institutional and tertiary usage.
These will match the design unitary consumptions in the significant area where the zone or sector being considered is located.

The percentage reflects the relation between usages that pour the water back into the sewer system and those which do not, and its deduction matches the amount that is subtracted from the designed supply flow due to irrigation in parks and gardens as well as other non-sewage consumption usages.

6.2. CRITERION FOR CALCULATING FLOWS IN UNDEVELOPED PLANNING AREAS FOR DESIGN PURPOSES

In order to calculate the future contribution of each consumption unit to the urban sewage flow, three groups have to be distinguished: multi-housing usage (apartment buildings), single-housing usage (individual houses) and industrial, institutional and tertiary usage. In each case, a proposed relative return rate is applied, depending on the different supply design unitary consumptions.

In accordance with its definition within the scope of this study, the supply design unitary consumptions for future properties include a proportion that corresponds to leaks in the distribution systems. This “purpose” does not contribute to the sanitation flow and is therefore excluded from the urban sewage calculations that the project is dealing with.

6.2.1. Multi-housing usage in undeveloped planning areas

In this case, it was considered **95%** of the design unitary consumptions for the future design of supply facilities for multi-housing usage in the sector under study. This supply design unitary consumption for domestic usage in multi-housing buildings on future planning ground was established as 8 l/m^2 that can be built on per day.

The **5%** discount corresponds to the proportion of existing leaks that should not be taken into account.

6.2.2. Single-housing usage in undeveloped planning areas

In this case, it has been considered **80%** of the design unitary consumptions for the future design of supply facilities for single-housing usage in the sector under study. The supply design unitary consumption for domestic usage in single-housing buildings on future planning ground was established as 9.5 l/m^2 that can be built on per day.

This return rate responds to the superimposition of:

- **15.8%** that corresponds to exterior usage in this kind of buildings, according to the supply design unitary consumption document settled on by Canal de Isabel II Gestión.

- **5%** discount on the above result, corresponding to the proportion of existing leaks that should not be taken into account.

6.2.3. Industrial, Institutional and Tertiary use in undeveloped planning areas

In this section, it has been considered **85.5%** of the design unitary consumptions for the future design of supply facilities for industrial, institutional and tertiary usage in the area under study.

This percentage reflects a **90%/10%** relation between the usages that return water back to the sewage system and those that do not (garden irrigation and other non-sewage consumption usage), on which a **5%** discount is applied corresponding to the proportion of existing leaks that should not be taken into account.

6.3. SUMMARY OF THE APPLICATION FOR CALCULATING

The following formula will be applied to the calculation, taking into account the design unitary consumptions in litres per square meter that can be built on:

Q_sanitation = [Dmv]·number_multi-housing+ [Duv·(1-Euv)]·number_single-housing+ [D·(1-K)]·area

The table 4 shows the rates that are to be applied to the calculation formula for urban sewage flows for design purposes, according to concept and ground type, either developed urban ground or ground included in urban planning as future development.

TABLE 4. CONCEPTS USED IN THE CALCULATION CRITERION FORMULATION. URBAN GROUND AND FUTURE URBAN GROUND IN PLANNING

Concept	*Calculation on ground for design purposes*	
	Urban development	*Planned urban development*
Domestic multi-housing usage **[Dmv]**	**100%** of present design unitary consumption	**95%** of future design unitary consumption
Domestic single-housing usage **[Duv]**	**100%** of present design unitary consumption	**95%** of future design unitary consumption
Domestic single-housing exterior usage **[Euv]**	**27%** of present design unitary consumption	**15.8%** of future design unitary consumption
Industrial, institutional and tertiary usage **[D]**	**100%** of present design unitary consumption	**95%** of future design unitary consumption
Non-consuming usage factor for industrial, institutional and tertiary usage **[K]**	**10%**	**10%**

This leads to the following application summary for calculating all scenarios, taking into account the calibration scenario used in the chapter on the proposed new criterion's validation.

Q_sanitation =	**[Dmv·(1+S)]·Number_Multi-housing**	*Multi-housing*
	+ [Duv·(1+S-Euv-S·Euv)]·Number_Single_housing	*Single-housing*
	+ [D·(1-K)]·Area	*Areas to use for design purposes on developed urban ground or future development*
	+ [Di·(1+S)]·Area	*Industries for calibration on developed urban ground*
	+ [Dc·(1+S)]·Area	*Businesses for calibration on developed urban ground*
	+ [Dy·(1+S)]·Area	*Institutional usage for calibration on developed urban ground*
	+ [Fa+P+L]·Area	*Estimated fraud, drains and cleaning for calibration on developed urban ground*

The definitions of these concepts appear in the table 5.

TABLE 5. CONCEPTS USED IN THE CALCULATION CRITERION FORMULATION AND CALIBRATION

Concept	*Design on developed ground*	*Future planning design*	*Calibration*
Domestic multi-housing usage **[Dmv]**	Present design unitary consumption	95% of future design unitary consumption	Real meter reading
Domestic single-housing usage **[Duv]**	Present design unitary consumption	95% of future design unitary consumption	Real meter reading
Domestic single-housing exterior usage **[Euv]**	**27%**	**15.8%**	**27%**
Under-metering **[S]**	-	-	**10%** (approximate, according to range and period)
Industrial, institutional and and tertiary usage (single) **[D]**	Present design unitary consumption	95% of future design unitary consumption	-
Non-consuming usage factor for institutional usage **[K]**	10%	10%	-
Industrial usage **[Di]**	-	-	**90%** of real meter reading
Commercial usage **[Dc]**	-	-	**90%** of real meter reading
Institutional usage **[Dy]**	-	-	**90%** of real meter reading
Estimated fraud **[Fa]**	-	-	**100%** according to balance chapter
Estimated or calculated drains **[P]**	-	-	**100%** according to balance chapter
Estimated or calculated pipe and facility cleaning **[L]**	-	-	**100%** according to balance chapter

7. Evaluation of the significance of the criterion change

After having validated the criterion and formulated its application for calculating flows in present and future scenarios, it was proceeded to quantify the impact that could result from adopting the new determination method for design flows for the sewage treatment system of the Community of Madrid.

In order to evaluate the possible impact the project has worked with designing scenarios for present and future horizons. Within these analyses, the most important ones are the present design scenario and the long-term scenario.

On the present horizon, with the design scenario, the project's team managed to confirm a rate change between the design of sewage and supply flows, prompted by the change of the calculation criterion for sewage flows.

Equally it was confirmed that on the present horizon this change is significant, after comparing the design results for the existing sewage treatment plants, by simulating a hypothetical *a posteriori* redesign of the daily maximum flows.

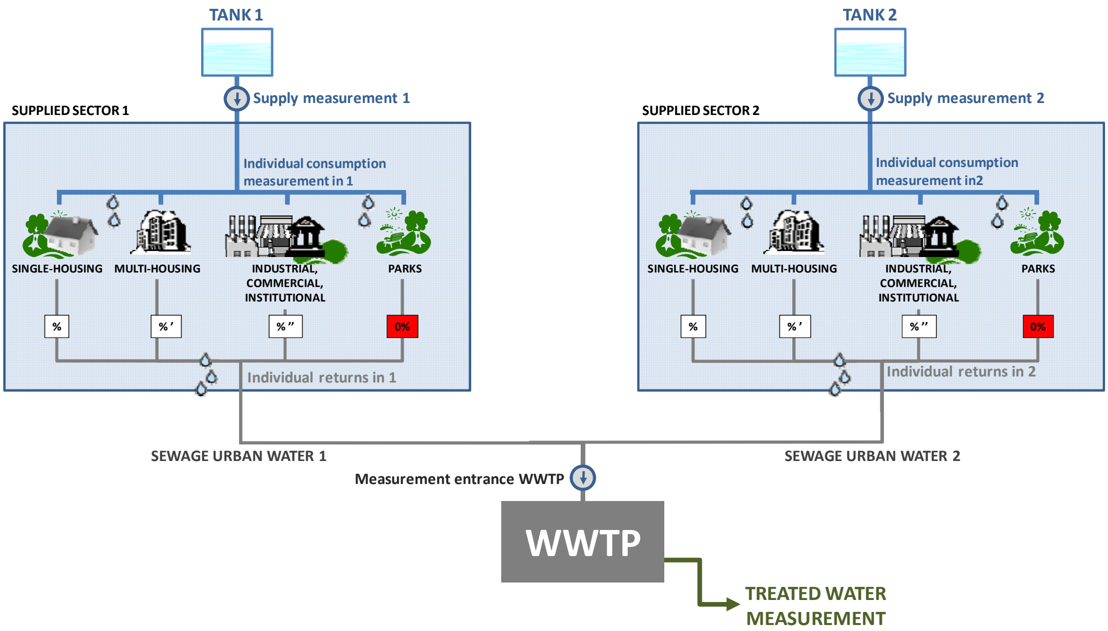
On the long-term design scenario, the criterion change's impact was analysed by quantifying the changes of sewage flow designs (average flows on the day of maximum consumption) for both new sewage treatment plants and the extension of existing facilities, included in the future plans in the Community of Madrid.

This analysis was done by applying the appropriate return rates to the individual consumption units regarding supply flows included in long-term planning, with the corresponding design unitary consumptions. In this way, the corresponding sewage flow was calculated in this scenario, for each WWTP included in the study, comparing the results with those achieved by the traditional method (with a constant rate of 80% of the designed supply flow). This analysis is included in the figure 19.

Urban sewage flow = ∑ (supply_design_unitary_consumption x return_rates) i

Peak day average flow at WWTP = Total of supply design unitary consumptions with their corresponding return rates

FIGURE 19. WORK DIAGRAM FOR THE PROPOSED CRITERION'S VALIDATION



7.1. VERIFICATION OF THE CHANGE PRODUCED IN THE RATIO BETWEEN THE DESIGNS FOR URBAN SEWAGE FLOWS AND SUPPLY FLOWS

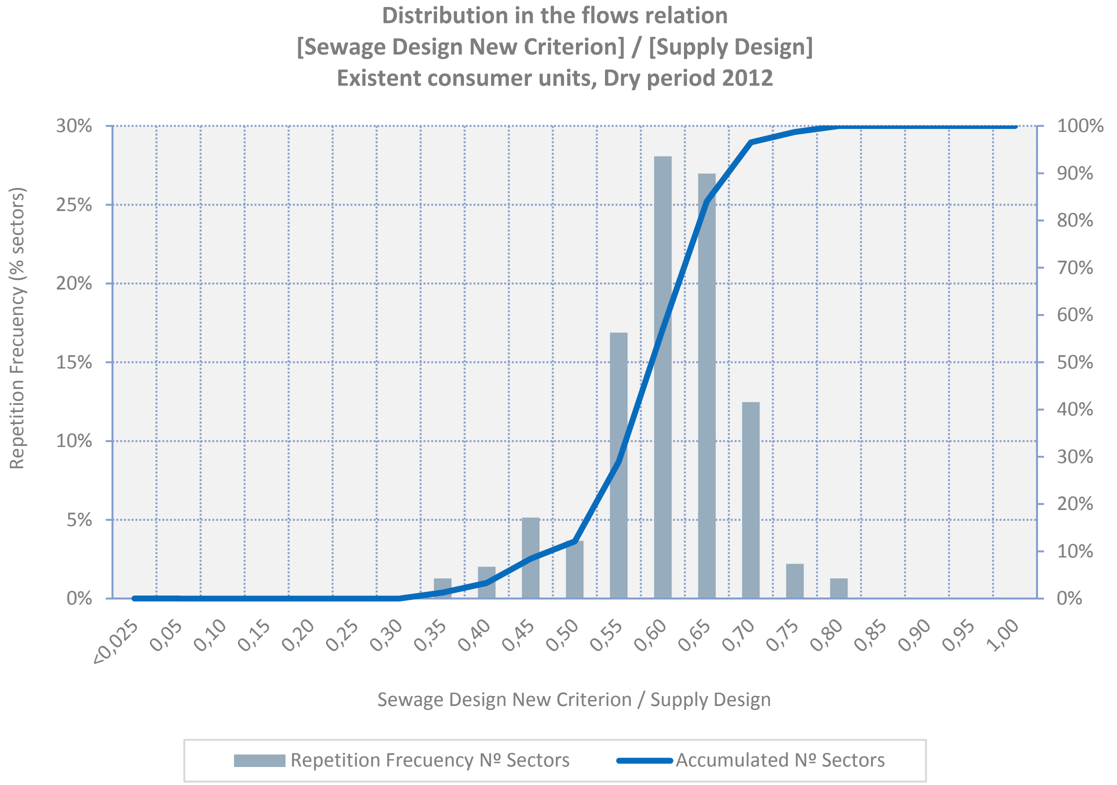
The object of this study is not to propose a change of ratio between the designs for sewage flows and supply flows, but to find a more precise and more adaptable calculation method for sewage flows. Even so, there is no doubt that the comparison of resulting ratios in real design situations can clearly show the impact achieved by the new criterion. This comparison is made clear in the following sections for the design scenario (daily maximum consumption) on the present horizon (existing properties as at December 2012).

7.1.1. Significance of the change of criterion for the "supply sector" scale

On the "Supply sector" scale, the relation between the **sewage flow for design purposes** calculated by means of the proposed criterion and the **supply flow for design purposes** was confirmed.

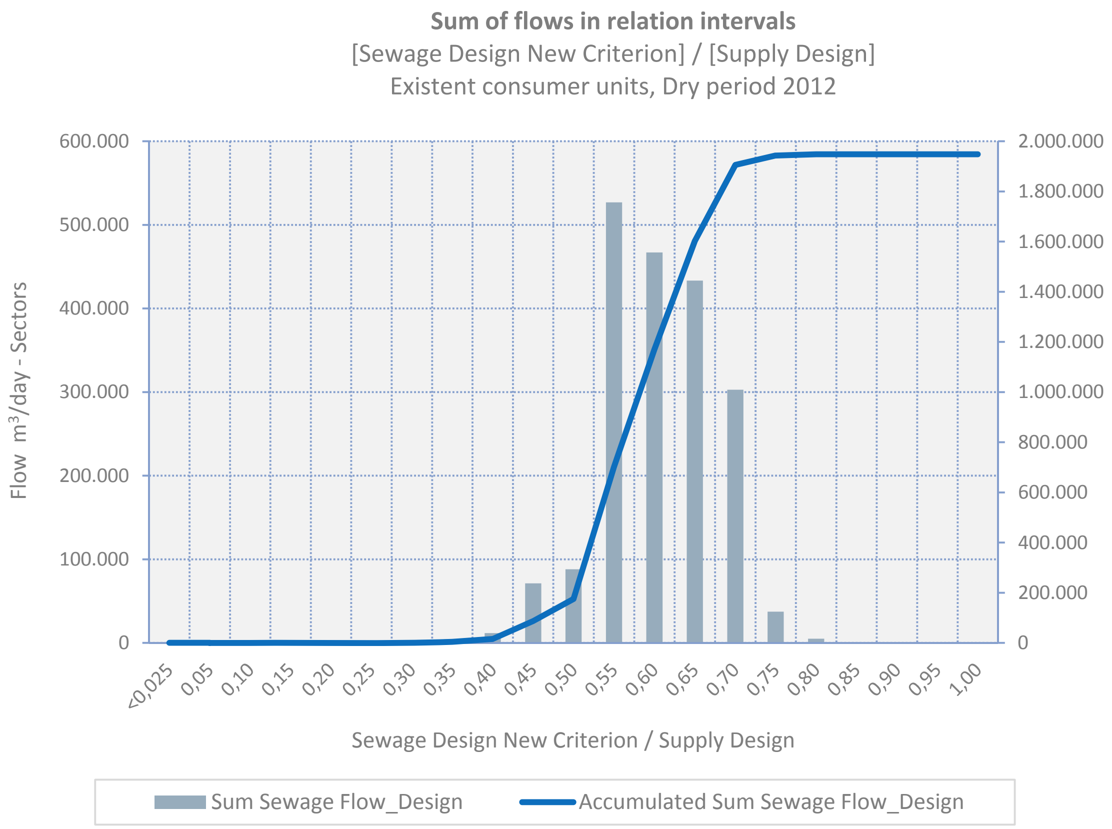
The figure 20 shows this relation by representing the repetition frequency of ratio intervals between **designed sewage** (according to the new criterion) and **designed supply**.

FIGURE 20. **SECTOR DISTRIBUTION ACCORDING TO THE RATIO BETWEEN THE DESIGNS OF NEW CRITERION SEWAGE FLOWS AND SUPPLY FLOWS**



As far as flows are concerned the figure 21 shows the accumulated urban sewage flow in each studied ratio interval, for the same ratio intervals between design flows as above.

FIGURE 21. ACCUMULATED FLOW DISTRIBUTION ACCORDING TO THE RELATION BETWEEN THE DESIGNS OF NEW CRITERION SEWAGE FLOWS AND SUPPLY FLOWS AT SECTOR LEVEL

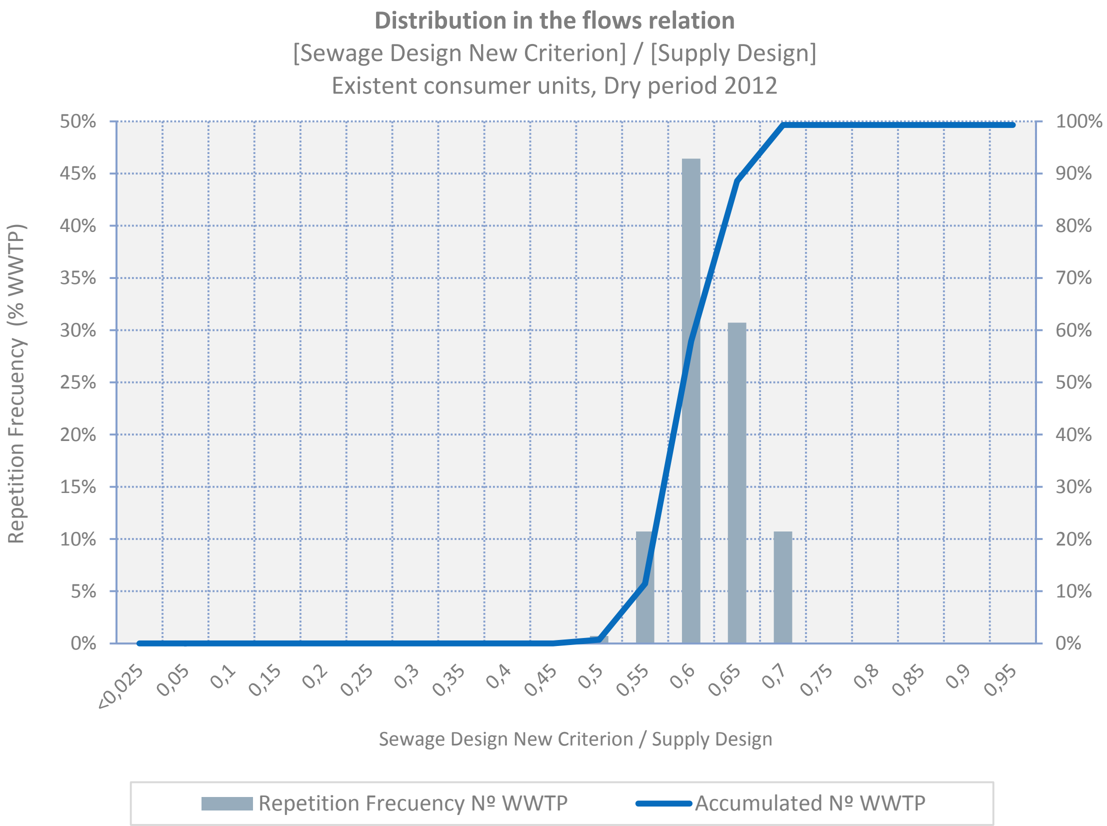


7.1.2. Significance of the change of criterion for the "Sewage Treatment Plant" scale

Organizing the sectors according to their sewage treatment plant drainage basins, the conditions for design purposes change, due to the introduction of simultaneity rates. The figures 22 and 23 represent the obtained results that show the analysed relation's obvious concentration between the ratios of 55% and 70%.

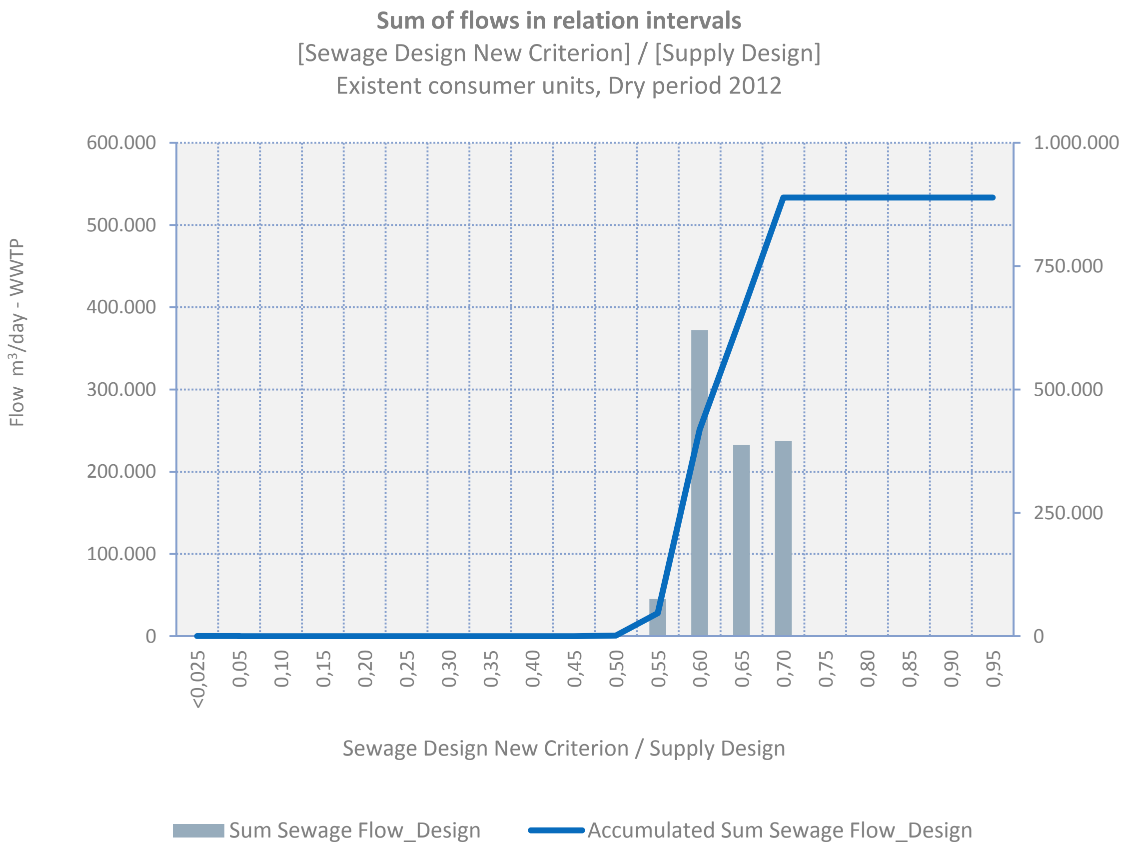
The relation is that between the **sewage flow for design purposes at WWTP entrance**, calculated by means of the proposed criterion, and the **supply flow for design purposes** of the sectors that drain towards the plant, taken from the existing consumption units.

FIGURE 22. **WWTP DISTRIBUTION ACCORDING TO THE RATIO BETWEEN THE DESIGNS OF NEW CRITERION SEWAGE FLOWS AND SUPPLY FLOWS**



Based on this WWTP distribution, according to the ratio between **the designs of sewage flow and supply flow**, **the accumulated urban sewage flow for design purposes** is calculated for each interval.

FIGURE 23. ACCUMULATED SEWAGE FLOW DISTRIBUTION ACCORDING TO THE RELATION BETWEEN THE DESIGNS OF NEW CRITERION SEWAGE FLOWS AND SUPPLY FLOWS AT WWTP LEVEL



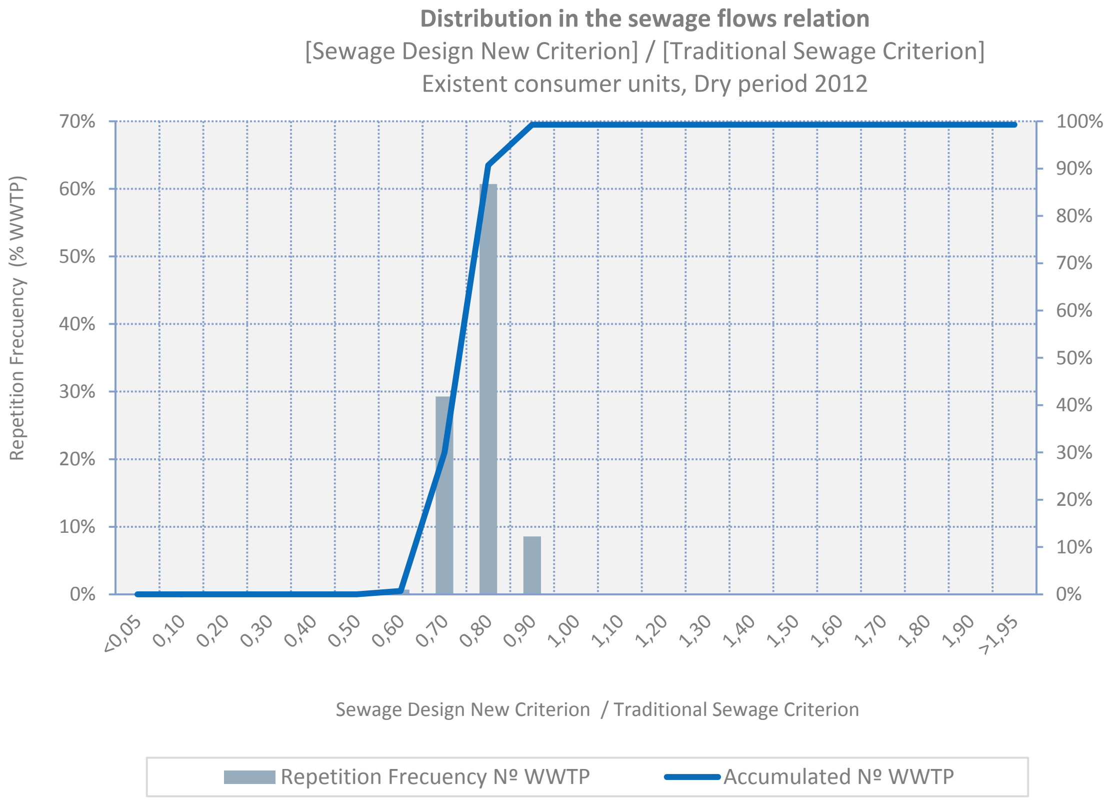
The proposed criterion's application to the design of sanitation and sewage treatment infrastructures led to important differences in comparison to the traditional criterion, reducing the resulting values from 80% to approximately 65%.

7.2. EVALUATION OF THE IMPACT OF THE CHANGE OF CRITERION WHEN PLANNING IN A REAL SEWAGE TREATMENT SYSTEM. COMPARISON WITH THE TRADITIONAL CRITERION

7.2.1. Analysis for the case of Sewage Treatment Plants on the present horizon

The following curve shows the frequency of the ratio between the designs of sewage flows with the proposed criterion and the traditional one (80% of supply). In the analysed cases, the design of sewage flow on peak days is reduced by approximately 10%, in comparison to the values achieved by the traditional criterion (see the figure 24).

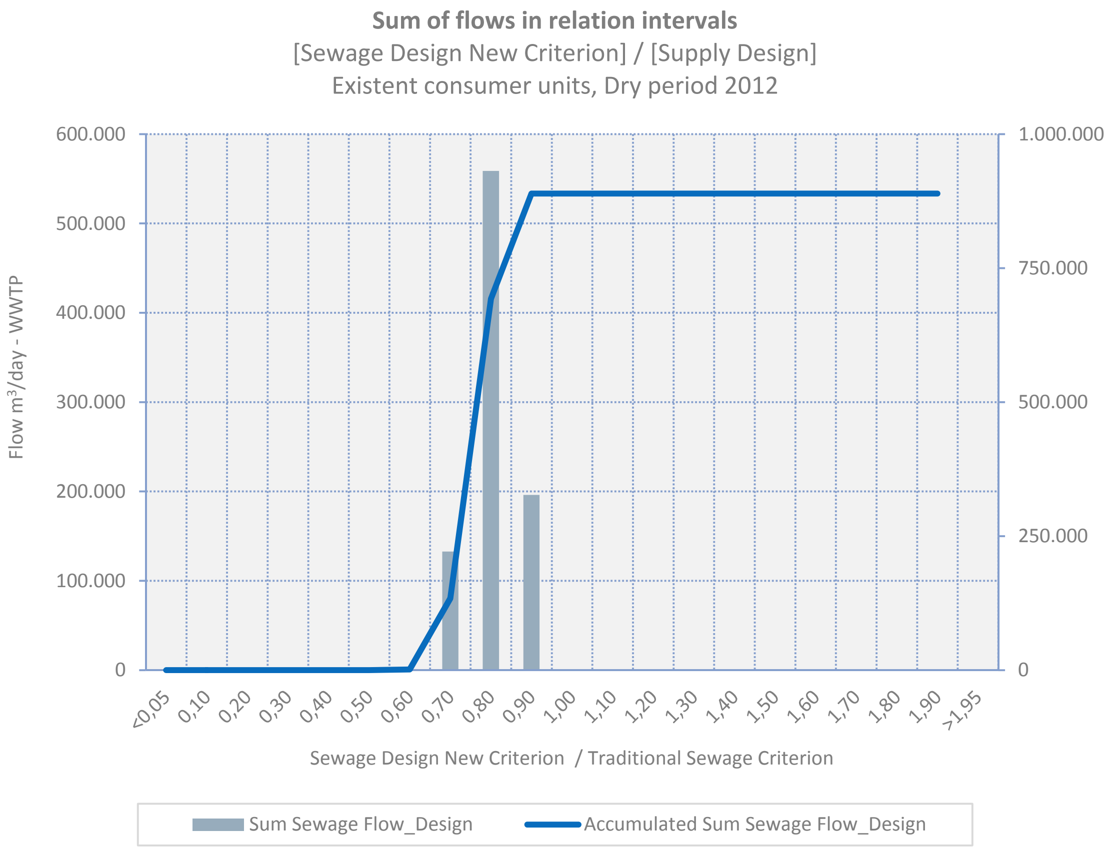
FIGURE 24. WWTP DISTRIBUTION ACCORDING TO THE FLOW RATIO: DESIGN OF NEW CRITERION SEWAGE VS. TRADITIONAL CRITERION



The same analysis was carried out with the sewage flows treated that correspond to each case, instead of the number of sewage treatment plants. In this way, the importance of the WWTPs that show a ratio that is higher than 0.8 (between the sewage flow calculated by means of the proposed criterion and those calculated at 80% of the supply flow) can be observed. Also, the WWTPs with lower design flows turned out to be those with higher discounts. See the figure 25.

The interpretation of these two figures shows clearly that by the application of the proposed new criterion to the design of sanitation and sewage treatment infrastructures the necessary investments will be smaller.

FIGURE 25. ACCUMULATED FLOW DISTRIBUTION ACCORDING TO THE RELATION BETWEEN THE DESIGNS OF NEW CRITERION AND TRADITIONAL SEWAGE FLOWS AT WWTP LEVEL



7.2.2. Comparison of design results for sectors on the present horizon

Just as in the two figures shown above, the figure 26 represents the comparison of the two criteria on the sector level.

It shows the gap generated by the two calculation criteria, the new one and the traditional one, for urban sewage flows, according to each ratio interval.

In this way, the accumulated difference in the flows of each criterion becomes more obvious than on the WWTP level.

The accumulation of calculations for individual sectors does not exactly match the results on the WWTP level because the peak rate for the day of maximum consumption depends on the amount of properties the calculation is based on.

If the calculated sewage flows for design purposes carried out with the proposed new criterion is compared to the sewage flow that is really being treated at the WWTPs in a variation graphic (see the figure 27), it can be clearly seen that the application of the proposed new criterion relies on a safety margin, or in other words, that the new criterion turns out to be reliable in its applicability.

FIGURE 26. FLOWS DIFFERENCE BETWEEN THE TWO CRITERIA ON SECTOR LEVEL FOR DESIGN PURPOSES

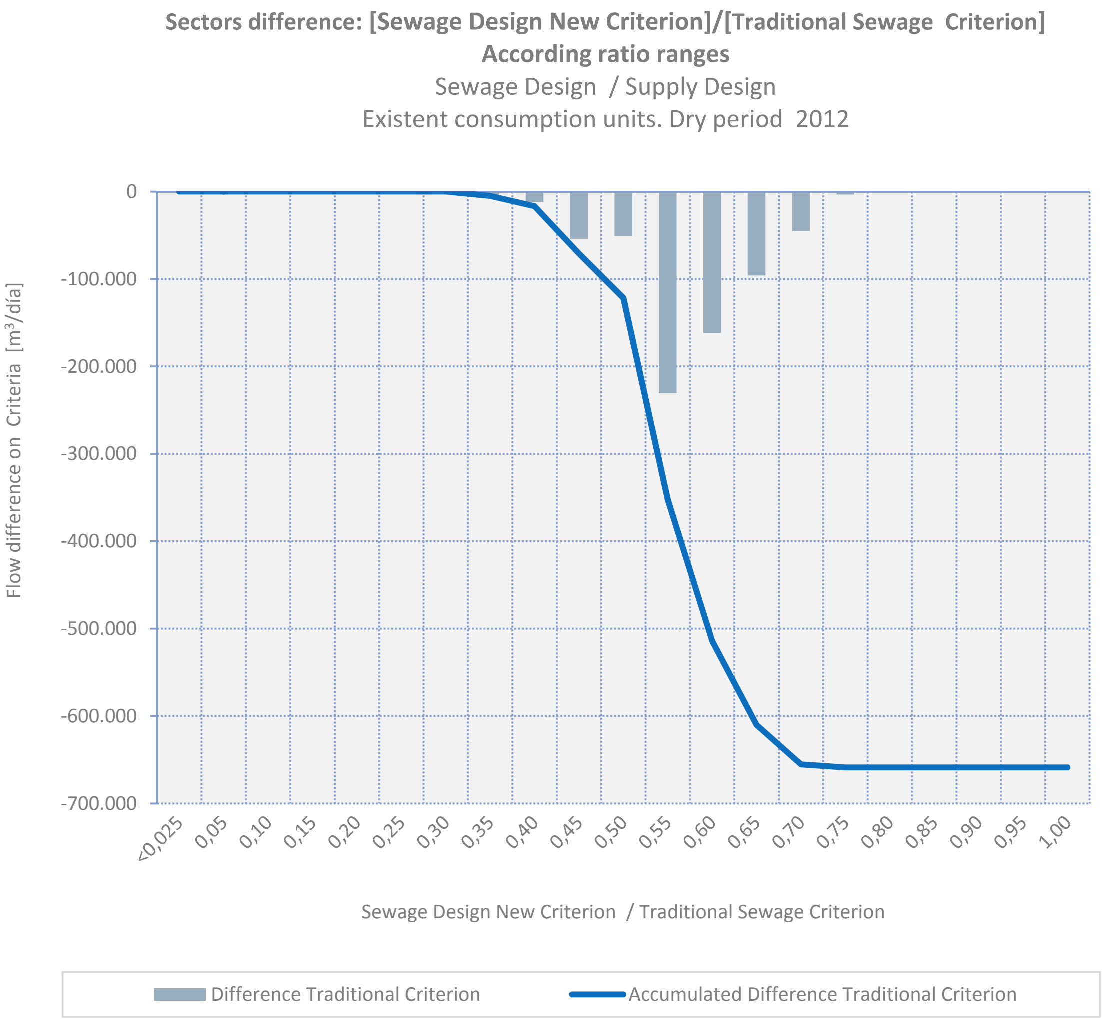
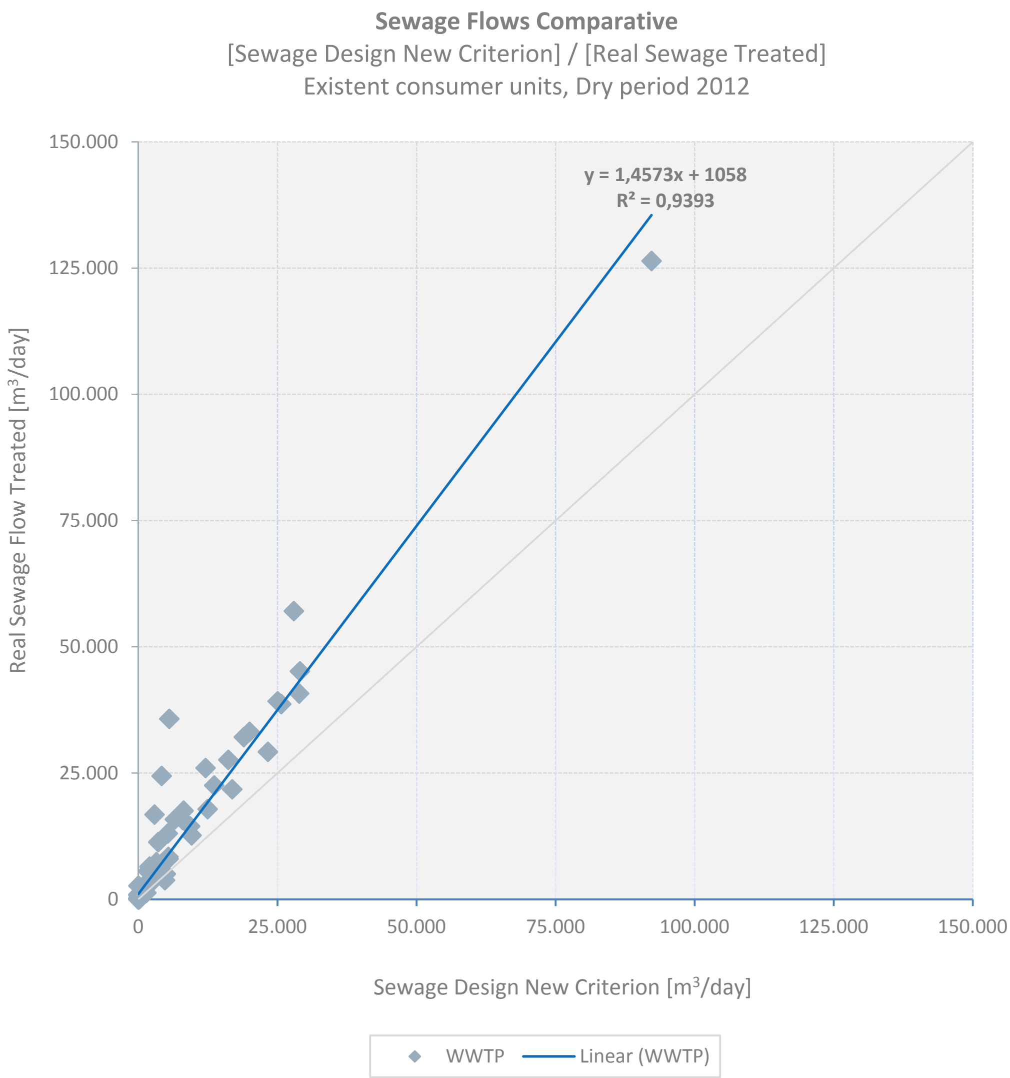


FIGURE 27. SEWAGE FLOW COMPARISON BETWEEN NEW CRITERION AND REAL VALUES FOR DESIGN PURPOSES

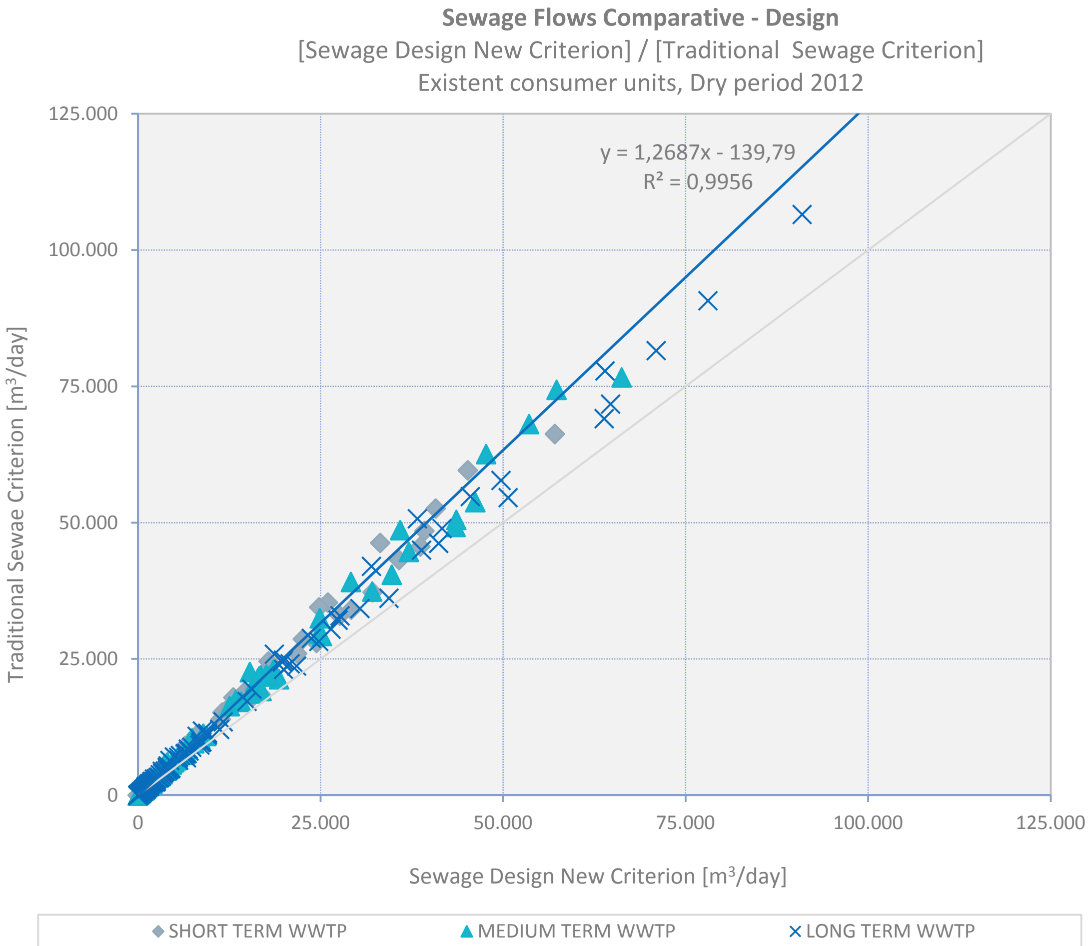


The confirmation of the calculated sewage flows with the traditional criterion and the new one for design purposes was added to different short-, medium- and long-term scenarios.

The results for the present scenario are shown in the figure 28.

The analysis leads to the conclusion that sizing by the traditional criterion has an effect that turns out to be too conservative. Therefore, the application of the proposed new criterion to the planning and design of sanitation and sewage treatment infrastructures would lead to smaller investments in comparison to the traditional criterion, as shown in the following section.

FIGURE 28. COMPARISON OF SEWAGE FLOWS BETWEEN THE TWO CRITERIA FOR DESIGN PURPOSES

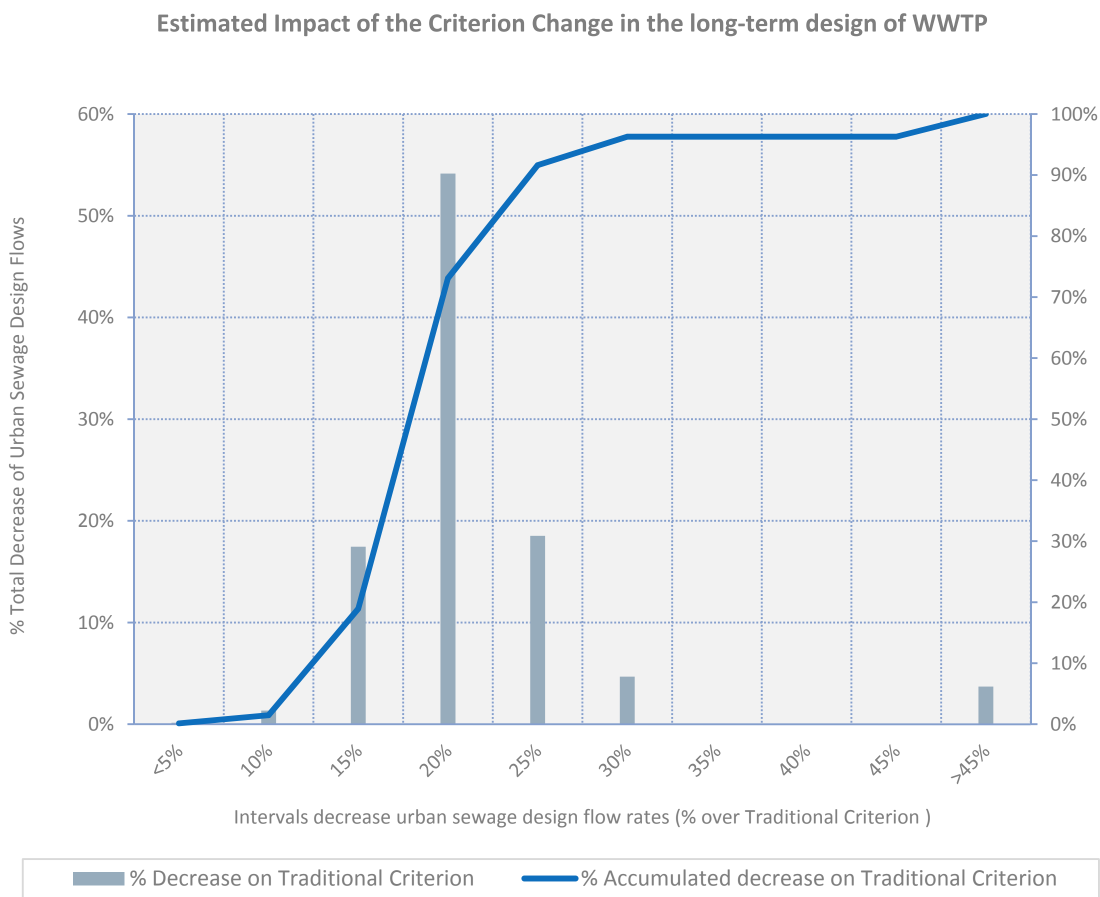


7.2.3. Evaluation of the significance for future planning

Taking into account a long-term horizon (year 2027), it was compared the daily water flow requests for the day of maximum consumption, calculated with the proposed new criterion and the traditional one, both for sewage treatment plants that have to be extended and those that are being planned (according to Canal de Isabel II Gestión's Investment Planning).

In this way, it was concluded that the adoption of a calculation method for urban sewage flows based on individualized return rates for each type of water usage leads to results that reduce the global flow by 15%, compared to the calculation carried out with the traditional criterion. 74% of the measures planned for this horizon show a reduction of sewage flow between 10% and 25%, and therefore are responsible for 90% of the calculated total reduction. In particular, 37% of the planned measures show a reduction of sewage flow between 15% and 20%, which adds up to 54% of the total reduction. (See the figure 29).

FIGURE 29. **DISTRIBUTION OF THE OVERALL DIFFERENCE OF DAILY FLOWS FOR DESIGN PURPOSES ON INDIVIDUAL PERCENTAGE REDUCTION INTERVALS IN COMPARISON TO THE TRADITIONAL CRITERION FOR LONG-TERM PLANNING OF SEWAGE TREATMENT PLANTS IN THE COMMUNITY OF MADRID**



8. Conclusions

A large variation can be observed regarding the ratio between water supply flow and the sewage flow that is returned to the sanitation systems.

In available measurements with reliable verifications, these ratios can vary between 40% and 90% in different areas, with the most frequent values concentrated around 60%, that is to say, quite different from the traditionally accepted value of 80%.

The application of the proposed criterion adapts much better to the characteristics of diverse water usages that occur in different zones. The confirmation of hypothesis and real measurements carried out within this study has led to important validations regarding the samples of high reliability. The most frequent values point towards a 100% match between measured values and calculated ones achieved by applying the new criterion.

The variation regarding confirmation ratios should not be interpreted as a reduction in the proposed criterion's validity nor as a reduction in the measurements' reliability, but as a sign of the variation that actually does exist regarding the single criterion proposed for each consumption unit and type, as well as the variation with regard to leaks (existing and apparent ones) in the distribution and sewer networks.

The theoretical application of the supply percentages with the new criterion to the present situation in the entire Community of Madrid (by sector) leads to regional variations between 35% and 80%, with 70% of all cases concentrated between 55% and 70% (design sewage flow compared to design supply flow).

A similar evaluation with zonal groups according to the WWTPs' drainage basins leads to an even higher concentration of 90% of the WWTPs concentrated in the range between 55% and 70%.

This means that the **proposed new criterion** is validated by confirming that for the group of highest reliability the sewage flow calculated by means of the new criterion amounts to about 100% of the real sewage flow treated at these WWTPs.

It can therefore be concluded that the **traditional criterion** leads to oversizing sanitation and sewage treatment infrastructures, since for the group of highest reliability the treated sewage flows in 82% of the cases are below 80% of the supply flows, according to real measurements.

It was also possible to confirm that the **proposed new criterion** adjusts itself better to **the real sewage flow** in comparison to the **traditional criterion**.

Therefore the **application of the new criterion supposes economic savings** as well as a **more efficient management** in planning sanitation and sewage treatment infrastructures, both at present and in the future, if the boundary conditions within the water supply and sewage treatment system make its application possible.

9. Appendices

9.1. APPENDIX 1. DATA AVAILABLE FOR THIS STUDY

The development of the proposed criterion is based on the following sources of information on consumption components and on the availability of real data regarding the phases of the complete urban water cycle:

- **Individual consumption measurements classified by usage type**
  Domestic (both, single- and multi-housing), industrial, commercial, institutional and other usage, irrigation. These data come from Canal de Isabel II Gestión's Corporate Commercial System (Greco). In 2012 there were 1,342,353 active contracts registered with individual meters, belonging to measured and/or topologically and geographically identified sectors. The available data used for this study are also based on those of August 2012.

- **Consumption microcomponents**
  Consumer monitor panel (active in 2012 and before), used for establishing the proportion of final usages (showers, lavatories, irrigation, etc.) for every consumer, especially in single- and multi-housing buildings. The source of information is the number 4 of the series Booklets of Research, Development and Innovation: "*Microcomponentes y factores explicativos del consumo doméstico de agua en la Comunidad de Madrid*"[6].

- **Project of sectorization, boundary and location** of all supply sectors
  This information is georeferenced and included in Canal de Isabel II Gestión's Corporate Geographic Information System (Gaudy). For the purposes of this study there are 693 sectors (either confined and measured, or identified for confinement and measurement, or planned for future developments).

- **Project of Sectorization, balances and uncontrolled water components on sector level**
  Supplied and metered water flows on sector level, including consumer and consumption classification. Data on supply timetables and monthly balances are available for 343 sectors during the analysis period of 2012.

- **Reference basins for each WWTP** (sewage treatment plant) within Canal de Isabel II Gestión's Sewage Treatment System. This information is georeferenced and included in the Corporate Geographic Information System (Gaudy) of the company. There are 147 drainage basins with their corresponding WWTPs.

- **WWTP controlled flows**
  Data available from the Corporate Remote Control System and the measurements validated by the company's Operation of Sewage Treatment unit.

[6] *Cuadernos de I+D+i* nº. 4 *Microcomponentes y factores explicativos del consumo doméstico de agua en la Comunidad de Madrid* (Microcomponents and explanatory factors of domestic water consumption in the Community of Madrid), Canal de Isabel II, Madrid (2008).

- **Correlation of each supply sector and the WWTP where its urban sewage is treated**

- **Criteria for the consideration of design unitary consumptions** for sizing the supply and distribution system in urban planning. The information regarding the supply design unitary consumptions for design purposes comes from internal documents, written by the "work group for studying supply design unitary consumptions calculation", for application in the company's Plan of Strategic Infrastructures[7].

- **Series of data from weather stations** in order to establish the precipitation in the drainage basins (measured in millimetres) and carry out this study in a period of little rainfall (dry period).

[7] *Normalización de evaluación de las demandas para la planificación y proyecto de las infraestructuras de abastecimiento* (Standardization of demand evaluation for planning and projecting supply infrastructures), Canal de Isabel II, Madrid (revisions of March 2009 and December 2011).

9.2. APPENDIX 2. RELIABILITY OF THE DATA

The verification and validation of the proposed criterion made it necessary to pay special attention to the reliability of the data concerning sector supply flows and WWTP sewage flows.

Equally important were the **combinations of reliabilities** for the groups of sectors that send their sewage water to the same WWTP, as well as these combined with the reliability of the data available on the WWTP.

A decision was taken to use the most recent period with stable weather and representative water flows at the WWTP entrances, which is why the interval of available data for June and July 2012 was chosen. The absence of rainfall of any consequence made it possible to work with a precise relation of treated sewage flows at each WWTP, putting them on an equal footing with the urban sewage flow generated in the sectors that belong to each WWTP's drainage basin.

9.2.1. Reliability of measurements of supply to sectors

The **reliability of measurements of supply to sectors** is defined in the project of sectorization by means of a numerical scale from 1 to 7 (with 7 representing the highest reliability). Various filter values were applied to the data of summer 2012 that were used for this study.

The following seven reliability criteria were used for the sectors during the period of analysis:

Criterion 1: Uninterrupted service of the measurement device

Criterion 2: Adequate sizing of the measurement device

Criterion 3: Absence of data out of validation range

Criterion 4: Stable scope without significant changes in connections and infrastructures

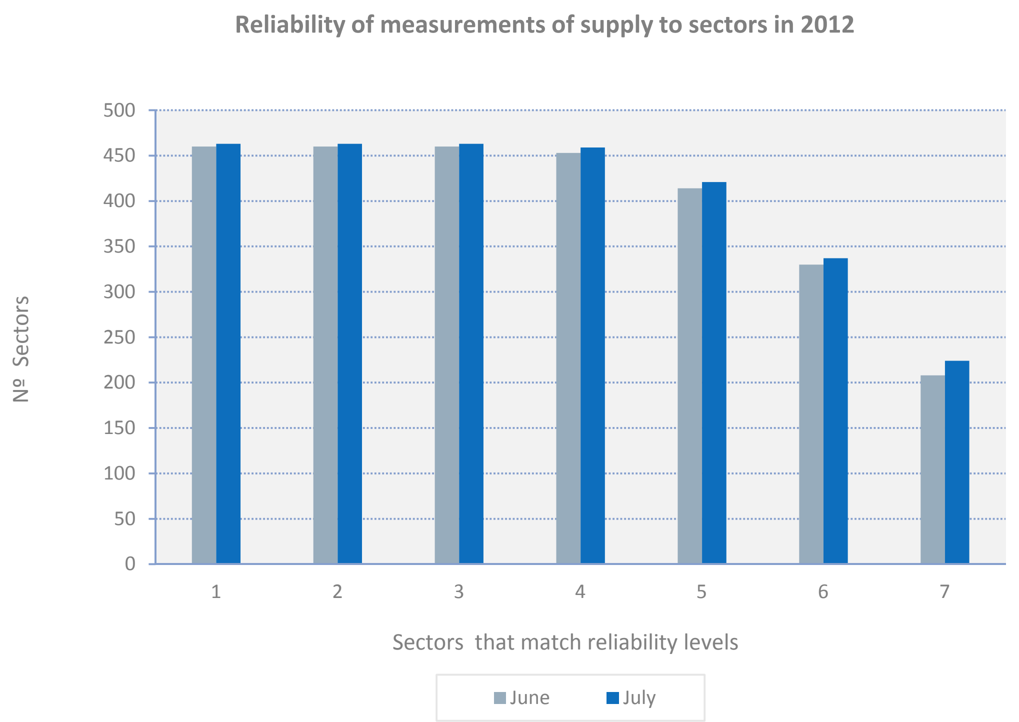
Criterion 5: Absence of significant manoeuvres on boundaries

Criterion 6: Validated balance of measurement/supply

Criterion 7: Measured supply values validated by model

The figure 30 shows the sectors that match each reliability level for the months of June and July 2012. During the study the 337 sectors that match reliability level 6 were used.

FIGURE 30. SUPPLY SECTORS AND RELIABILITY CRITERIA AND LEVELS



9.2.2. Reliability of sewage flow measurements at WWTP

The reliability of the sewage flow measurements at the sewage treatment plants was established by Canal de Isabel II Gestión's Operation of Sewage Treatment unit. For the purposes of this study a scale of two levels was applied:

- **Level 1**: sewage treatment plants with measurements of high reliability (55 WWTPs).

- **Level 2**: sewage treatment plants with flow data of medium reliability (remaining WWTPs, by omission).

For the purposes of this study, the most precise flow measurements at the WWTPs are those registered at their entrances. However, the available **reliable** measurements of treated sewage waters are those measured at the WWTPs' exits, that is to say, not the entering flow but the sewage flow really treated. Due to these circumstances, the analysed period was limited to the summer of 2012, which was extraordinarily dry, to avoid impreciseness. Under these conditions, it can be assumed that there were no unmeasured flows.

9.2.3. Combined data reliability

The combination of the reliability of sector groups according to WWTPs and the reliability of WWTP measurements leads to the work panel for each analysed scenario.

These scenarios can be organized in four groups:

- **Group 1 – maximum reliability**
  - All sectors that belong to the WWTP's drainage basin match the maximum reliability level (7).
  - The WWTP belongs to **reliability level 1.**

  In June 2012, this group was made up of 11 WWTPs.

- **Group 2 – high reliability**
  - All sectors that belong to the WWTP's drainage basin have high reliability, but not full (match 6 or 7 criteria).
  - The WWTP belongs to **reliability level 1.**

  In June 2012, this group was made up of 14 WWTPs.

- **Group 3 – medium reliability**
  - All sectors that belong to the WWTP's drainage basin match the maximum reliability level (match 7 criteria).
  - WWTP with any reliability (**levels 1 and 2**).

  In June 2012, this group was made up of 35 WWTPs.

- **Group 4 – without reliability filter**
  - All sectors and all WWTPs with any reliability level of either category
  - This group includes all WWTPs with available data as well as all sectors with available data

  In June 2012, this group was made up of 76 WWTPs.

9.3. APPENDIX 3. LIST OF FIGURES

Figure	*Title*	*Page*
1	RELATION OF THE REAL QUANTITIES OF WASTE WATER TREATED / WATER SUPPLIED	13
2	ALTERNATIVE CRITERION FOR CALCULATING URBAN SEWAGE FLOW	14
3	VERIFICATION OF THE CRITERION THROUGH REAL SUPPLIES IN RELIABLE SECTORS	16
4	THE NEW CRITERION'S CALCULATED IMPACT	19
5	RELATION BETWEEN SECTORS AND SEWAGE TREATMENT PLANTS	27
6	FREQUENCY DISTRIBUTION OF THE RELATION BETWEEN REAL SEWAGE FLOW AT WWTP AND REAL SUPPLY FLOW. MAXIMUM RELIABILITY	28
7	FREQUENCY DISTRIBUTION OF THE RELATION BETWEEN REAL SEWAGE FLOW AT WWTP AND REAL SUPPLY FLOW. HIGH RELIABILITY	29
8	VARIABILITY OF RELATION BETWEEN REAL SUPPLY FLOW TO SECTORS AND REAL SEWAGE FLOW AT WWTPS	30
9	FREQUENCY DISTRIBUTION OF THE RELATION BETWEEN REAL SEWAGE FLOW AT WWTP AND REAL SUPPLY FLOW. MEDIUM RELIABILITY	31
10	FREQUENCY DISTRIBUTION OF THE RELATION BETWEEN REAL SEWAGE FLOW AT WWTP AND REAL SUPPLY FLOW. WITHOUT RELIABILITY FILTERS	32
11	SEWAGE PERCENTAGE ACCORDING TO WATER USAGE	34
12	WORK DIAGRAM FOR THE PROPOSED CRITERION'S VALIDATION	38
13	VERIFICATION OF THE NEW CRITERION'S APPLICABILITY FOR MAXIMUM RELIABILITY MEASUREMENTS	43
14	VERIFICATION OF THE NEW CRITERION'S APPLICABILITY FOR HIGH RELIABILITY MEASUREMENTS	43
15	VERIFICATION OF THE NEW CRITERION FOR MAXIMUM RELIABILITY SECTORS	45
16	COMPARISON OF PROPOSED NEW CRITERION VS. TRADITIONAL CRITERION. WWTP	46
17	COMPARISON OF PROPOSED NEW CRITERION VS. TRADITIONAL CRITERION. URBAN SEWAGE FLOW IN WEIGHTED M^3	47
18	PROPOSED NEW CRITERION AND TRADITIONAL CRITERION IN COMPARISON TO REAL SEWAGE FLOW	48
19	WORK DIAGRAM FOR THE PROPOSED CRITERION'S VALIDATION	59
20	SECTOR DISTRIBUTION ACCORDING TO THE RATIO BETWEEN THE DESIGNS OF NEW CRITERION SEWAGE FLOWS AND SUPPLY FLOWS	60
21	ACCUMULATED FLOW DISTRIBUTION ACCORDING TO THE RELATION BETWEEN THE DESIGNS OF NEW CRITERION SEWAGE FLOWS AND SUPPLY FLOWS AT SECTOR LEVEL	61
22	WWTP DISTRIBUTION ACCORDING TO THE RATIO BETWEEN THE DESIGNS OF NEW CRITERION SEWAGE FLOWS AND SUPPLY FLOWS	62

Appendices

Figure	Title	Page
23	ACCUMULATED SEWAGE FLOW DISTRIBUTION ACCORDING TO THE RELATION BETWEEN THE DESIGNS OF NEW CRITERION SEWAGE FLOWS AND SUPPLY FLOWS AT WWTP LEVEL	63
24	WWTP DISTRIBUTION ACCORDING TO THE FLOW RATIO: DESIGN OF NEW CRITERION SEWAGE VS. TRADITIONAL CRITERION	64
25	ACCUMULATED FLOW DISTRIBUTION ACCORDING TO THE RELATION BETWEEN THE DESIGNS OF NEW CRITERION AND TRADITIONAL SEWAGE FLOWS AT WWTP LEVEL	65
26	FLOWS DIFFERENCE BETWEEN THE TWO CRITERIA ON SECTOR LEVEL FOR DESIGN PURPOSES	66
27	SEWAGE FLOW COMPARISON BETWEEN NEW CRITERION AND REAL VALUES FOR DESIGN PURPOSES	67
28	COMPARISON OF SEWAGE FLOWS BETWEEN THE TWO CRITERIA FOR DESIGN PURPOSES	68
29	DISTRIBUTION OF THE OVERALL DIFFERENCE OF DAILY FLOWS FOR DESIGN PURPOSES ON INDIVIDUAL PERCENTAGE REDUCTION INTERVALS IN COMPARISON TO THE TRADITIONAL CRITERION FOR LONG-TERM PLANNING OF SEWAGE TREATMENT PLANTS IN THE COMMUNITY OF MADRID	69
30	SUPPLY SECTORS AND RELIABILITY CRITERIA AND LEVELS	76

9.4. APPENDIX 4. LIST OF TABLES

Table	*Title*	*Page*
1	RETURN RATES	18
2	CONCEPTS USED IN THE CALCULATION OF NEW CRITERION FORMULATION. CALIBRATION SCENARIO	41
3	PROPOSED RETURN RATES ACCORDING TO USAGE TYPE AND CONSOLIDATION STATUS	51
4	CONCEPTS USED IN THE CALCULATION CRITERION FORMULATION. URBAN GROUND AND FUTURE URBAN GROUND IN PLANNING	55
5	CONCEPTS USED IN THE CALCULATION CRITERION FORMULATION AND CALIBRATION	56

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9.6. APPENDIX 6 GLOSSARY OF TERMS

WWTP	Waste Water Treatment Plant (Sewage plants, called EDAR in Spanish). Facility intended to reduce the pollutant load in waste water before discharge into a receiving medium.
SECTORS	Areas of water consumption with a permanent configuration where water inflow and outflow are monitored through flow meters with an hourly frequency.
SECTORIZATION	It is a project being presently carried out by Canal de Isabel II Gestión which is intended to the accurate identification, define of the boundary, characterization of the consumption areas and measurement of each one of the supply areas of consumption inside the Community of Madrid.
PROPERTY	Physical unit that consumes water or that returns water to the sewer system.
MICROCOMPONENTS	The microcomponents (final usages) of drinking water refer to each one of the purposes the water is used for within a property. In the context of domestic usage, the microcomponents distinguish between purposes such as showers, washing machines, dish washers, taps, lavatories, as well as exterior usage such as in patios and gardens. Canal de Isabel II carried out a specific project on this regard, published in the number 4 of the series Booklets of Research, Development and Innovation: *Microcomponents and explanatory factors on domestic water consumption in Comunidad de Madrid.*
SUPPLY SECTORS	Drinking water consumption areas.

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