TECHNIQUES FOR INSPECTION AND TESTING OF WASTEWATER COLLECTING SYSTEMS – ANALYSIS OF RESULTS OF CCTV INSPECTIONS

Pedro Garez Gomes

Department of Civil Engineering, Architecture and Georesources, IST, Technical University of Lisbon Av. Rovisco Pais, 1049-001 Lisbon, Portugal. pedro.garez@gmail.com

July 2013

ABSTRACT: Among the requirements of ISO 24511:2007 for the asset management of drainage systems, there is the condition assessment. This is a central aspect in the whole process of decision making in this area, especially with the progressive aging of the infrastructure that makes up the drainage systems and the need to conscientiously apply the limited resources, to ensure the growing demands on the part of entities legislators / regulators and the general public. In most cases, evaluating the condition of drainage systems means inspecting using CCTV (Closed-Circuit Television) and applying protocols to encode and classify the anomalies observed according to its severity. In addition to the simplifications and constraints underlying this solution, there are other sources of uncertainty in the process, particularly aspects regarding the operator who carries out the inspection and also the protocol used in the inspections. In this thesis, the major CCTV technological variants are reviewed, as well as different protocols are compared for classification and weighting of the anomalies. This thesis also presents the statistical analysis of the uncertainty arising from operator, particularly aspects of the ability to identify all of the anomalies and the application of protocols to estimate the degree of condition, based on the campaign results of periodic inspections that SANEST,S.A. has made to the emissaries of Caparide, Castelhana, Marianas and Sassoeiros. The aim of this study was to quantify the contribution to uncertainty in CCTV inspection, in particular concerns the identification of anomalies that exist and the estimated degree of condition.

Keywords: Asset management, CCTV inspection, Condition of sewer collectors, Drainage systems, Protocols inspection.

1. INTRODUCTION

The drainage systems and wastewater treatment are components of high importance. Currently, in the developed regions (including Europe, North America and Oceania), drainage systems serve about 90% of the population (WHO, 2000). In the U.S. the assets corresponding to the drainage network has a length estimated between 1 and 1.3 million kilometers (Tafuri et al. 2002). In underdeveloped or developing regions, attendance rates are lower at around 49% in Latin America and the Caribbean, 18% in Asia and 13% in Africa (WHO, 2000). However, these rates have tended to increase attendance and construction of drainage systems is seen as a prerequisite for sustainable development of these regions (UNICEF. 2006; UN 2011). As such, drainage systems represent a significant investment that extends in time and space, due to the need to ensure continuity and constant improvement of the existing infrastructure and developing new infrastructure to track the evolution / transformation of communities.

The drainage and wastewater treatment play key roles for the operation and sustainability of the communities, especially in safety (e.g. flooding, collapse of infrastructure), public health and environmental quality (ERTL and HABERL 2006). These infrastructures are vast networks that often have been forgotten because they are invisible or barely visible to the general public due to predominantly being developed underground. Often, maintenance operations only take place when the systems demonstrate malfunction and rehabilitation interventions generally take place after a severe failure. The less serious failures are resolved by minor repairs (ABRAHAM and GILLANI 1999). This strategy results in interventions based on reactive management with levels of difficulty and higher costs in comparison with planned interventions equivalents. To counter this attitude and ensure that system performance is maintained at an acceptable level, the NRC-CNRC (2004) recommends that the responsible entities should adopt a more sustainable management and investment in infrastructure, the knowledge of the type, characteristics and condition of the infrastructure, identifying needs and priorities for intervention.

In most cases, the assessment of the condition of drainage systems is performed through CCTV inspections, using standardized protocols to consider the severity of the observed anomalies. In addition to the simplifications and limitations underlying this solution, there are still other sources of uncertainty in the process, including aspects related to the operator carrying out the inspections and the protocol used for establishing the condition.

2. INSPECTION TECHNIQUES

The choice of the appropriate technique for inspection of buried infrastructure depends on several factors, including the material of the collector, if the collector is used for distribution of drinking water or wastewater and type of information to collect (Koo and Ariaratnam 2006). Regarding the type of information to be collected, the selection of the appropriate technique depends on the purpose of the inspection. The inspection can be carried out in order to obtain a positional recognition of the infrastructure or to inspect internally or externally the collector (Koo and Ariaratnam 2006).

2.1. Closed circuit television (CCTV)

The technology of Closed Circuit Television (CCTV) has been widely used in the inspection of collectors, since its introduction after World War II, one of the most used techniques alongside with personal inspection (Read and Vickridge 1997; WRc 2001; Koo and Ariaratnam 2006). This inspection technique consists in identifying the anomalies in sewer collectors by visualization of images collected by CCTV cameras which are introduced and moved along the collectors. Given the mobility of CCTV systems, inspection systems for CCTV can be classified as stationary or mobile (WRc 2001). In the first type of systems, the inspection camera is fixed on a manhole, where captures manifold. The camera can possibly be provided with system image magnification. Through this technology, the ability to detect defects is limited to those visible from the place where the camera is installed (Makar 1999). Given the limitations of observation in this technique, its use is mostly integrated in a process of priority selection of infrastructure for additional inspection (Makar 1999). Mobile systems are more commonly used for the inspection of sewers. Currently, it is common to use remotely controlled motorized robots. These are moved along the axis of the collectors, collecting images of anomalies in their passage. These systems may have adjustable speed and to allow control of the height of the camera and / or lights (Read and Vickridge 1997; WRc 2001). The collectors of smaller diameter in which the robot cannot enter, and the collectors with large diameters, in which it is not possible to divert the effluent, and the height and flow velocity prevents its use, it is common to mount the cameras on rafts which are dragged along the collector. One of the major problems of this alternative is the time necessary to immobilize the camera when it is necessary to inspect some section in more detail (Read and Vickridge 1997; USEPA 1999).

Currently there are commercially available mobile systems that allow the inspection of sewers with a diameter greater than 100 mm (USEPA 1999; WRc 2001). It is recommended that this technique is only applied in the inspection of sewers with diameters up to 1200 mm (USEPA 1999; WRc 2001). This is due to the fact that as diameter of the collector increases, distance between camera and walls increases and limits the ability to display anomalies. For larger diameters cameras should allow higher resolution images and more powerful lighting systems. The camera must be positioned to maintain the lens closest to the center of piping, in circular or rectangular collectors, or two thirds of the height in oval collectors (Read and Vickridge 1997; USEPA 1999).

2.2. Adoption of other techniques

Currently there are several methods available that allow meeting different purposes of inspection campaigns. The visual techniques are widely adopted by managers because they are well adjusted to the application protocols based on observation of anomalies to survey the condition of the collectors. However, these techniques have limitations in terms of implementation and anomaly detection, in particular for identifying faults in the submerged part of the collector due to the presence of debris in the wastewater flow and with the turbulence of the flow it becomes difficult to obtain images of sufficient quality to identify anomalies. These techniques also do not allow identification of problems in the outer envelope of the collector (Makar 1999). The physical and geophysical systems have been used as sources of supplementary information, in particular under conditions where inspections with CCTV are not viable. However, these systems do not have efficiency and confidence levels that allow them to replace the whole visual inspection, in particular due to the difficulty in interpreting the results (Makar 1999).

It should be noted multisensory systems for inspection ally different technologies in a single product, allowing collection of data through different sources and obtaining results in greater detail and precision than systems using a single technology inspection. The fact that these techniques are often associated to detection, automated validation and evaluation systems, allows that the error associated to uncertainty in evaluating the condition of collectors does not contemplate the error, present in traditional inspection by CCTV, of the inspector in identifying anomalies. From an economic point of view, the new inspection technologies generally have an initial cost greater than the visual inspection by CCTV and this may be a factor impeding the use of these technologies by firms performing inspection. Another impeding factor relates to the interpretation of the results of analyzes carried out by these new technologies, which require skilled and experienced staff to be able to analyze the data obtained in the investigations. This factor involves an investment by firms in the expertise of its staff in the use of these new technologies.

The adoption of new technologies in inspections collectors requires economic and sustainability studies to determine if the overall cost of adopting a new technology for inspection, including the costs of operation, can be smaller than a traditional inspection (SOUSA et al. 2006).

3. CLASSIFICATION PROTOCOLS

The inspection protocols began to be developed in 1977 by the Water Research Centre (WRC), UK. The best known is the protocol developed by WRc, which has been adopted all over the world in its original form or with minor adjustments to national or local level (WRc 2001; NRC-CNRC 2004).

At its core, the inspection protocols establish a set of rules to perform CCTV inspections and establish a system of categorization of observed anomalies. Usually the protocols distinguish between two groups of anomalies, including structural and functional (or operational) (Chughtai and Zayed 2008). The first group includes the anomalies that relate primarily to the performance of structural components, providing an indication of the likelihood of collapse. This group of anomalies is an indicator of the need for rehabilitation or replacement. The group of functional anomalies represent the anomalies that affect mainly the operation of the components. This group of anomalies identifies the need to perform maintenance on the system, including the cleaning or removal of roots (Opila and Attoh-Okine 2011).

In addition to coding anomalies, multiple protocols include, for each anomaly, a representative weight of its relevance to structural or functional condition. In addition, the condition of the components is usually assessed on a scale of decreasing condition from 1 to 5. The conversion of the weights of various anomalies in the degree of the corresponding component condition, the majority of protocols adopts a conservative approach and considers that the condition of the collector is constrained by the anomaly with greater weight. Table 1 presents the criteria to determine the condition of collectors based on maximum weight of anomalies observed, according to the protocols of the WRc and NRC.

Other approaches can be applied to consider the weights of anomalies, such as the total weight of anomalies, most suitable for manholes, or average weight of anomalies, most suitable for collectors, but the majority of protocols do not provide criteria for classifying condition from these approaches. An exception is the WRc protocol, which provides limits to determine the functional condition of the collectors according to the average weight of the anomalies.

Table 1- criteria to determine the condition of collectors based on maximum weight of anomalies observed, according to the protocols of the WRc and NRC.

CONDITION		WRc		NRC	
Scale	**Description**	**Structural**	**Functional**	**Structural**	**Functional**
0	Excellent condition	-	-	0	0
1	Acceptable condition	<10	<1	1 - 4	1 - 2
2	Minimal risk of collapse with some potential deterioration	10 - 39	1 - 1.9	5 - 9	3 - 4
3	Collapse unlikely with potential for deterioration	40 - 79	2 - 4.9	10 - 14	5 - 6
4	Probable collapse	80 - 164	5 - 9.9	15 - 19	7 - 8
5	Imminent collapse or collapsed collector	165	10 - 20	20	9 - 10

4. DRAINAGE SYSTEM OF SANEST,S.A.

SANEST,S.A. - *Saneamento da Costa do Estoril, S.A.* is responsible for the construction, management and operation of the sanitation system of Estoril Coast. The management and operation of this system is under concession until the year 2020. The company is responsible for the collection, treatment and final rejection of urban waste water from approximately 800,000 inhabitants-equivalents of the Estoril Coast.
The system managed by SANEST, S.A. covers an area of 220 km2, which corresponds to the entire municipality of Cascais, most municipalities of Oeiras and Sintra and a small part of the municipality of Amadora. It consists of an interceptor, with a length of 24.7 km, which extends along the coastline from Linda-a-Velha to Cascais, more precisely to the water treatment station of GUIA, where effluents are treated and rejected in the Atlantic Ocean to 45 m depth, through a marine outfall of 2.7 km long. The interceptor collects the wastewater collected by the 20 emissaries installed along the main water lines, making a total length of 120 km, and is complemented by nine pumping stations.
In the context of this thesis campaign results of periodic inspection by CCTV that SANEST has been holding to the emissaries of Caparide, Castelhana, Marianas and Sassoeiros were analyzed, despite that SANEST holds since 2005, periodic inspections by CCTV to all 20 outfalls that make up the drainage system.

5. CASE STUDY

5.1. Uncertainty in CCTV inspections

The limitations characteristic of the CCTV inspections result that these type of inspection only allows detection of anomalies visible in the images captured from the inner surface of the collectors, being impossible to detect anomalies in areas where there is flow, water retention, sediment or other type of obstacle to viewing. The characteristics of the cameras (eg, resolution, ability to image magnification and camera movement), the lighting power of the equipment and the conditions of the collector at the time of inspection are the most relevant parameters regarding the technical nature of the uncertainty CCTV inspections (Read and Vickridge 1997; Koo and Ariaratnam 2006).
Beyond technical issues, the CCTV inspection still depends on the inspector in charge and the protocol used. The analysis of images collected is a long process, subjective and very dependent on the technician that is analyzing them. The identification and classification of anomalies may vary from technician to technician, depending on the experience and competence of each, and between inspections, depending on the concentration and fatigue of the technician at the time. The protocol used influences the assessment of condition due to the anomalies that are taken into consideration,

what their relative importance is and the criteria to convert the weight of the anomalies in the condition of the component (Read and Vickridge 1997; Koo and Ariaratnam 2006).

Despite the innovations recorded at the level of technology of CCTV equipment, which contributed significantly to improving the quality of visualizing anomalies, the uncertainty associated with the technician who performs the inspection and the subjectivity of the protocol used persists.

5.2. Uncertainty of the inspector in identification of anomalies

In evaluating the uncertainty of the CCTV inspector in identifying anomalies in collectors, for this thesis the difference in the number of anomalies between consecutive inspections by emissary was examined. The emissary of Sassoeiros was not considered in this analysis, for only having data from CCTV inspections with deficiencies coded according to the protocol of EN 13508-2, for a single inspection campaign.

Figure 1 shows, in percentage terms, the difference between the number of anomalies detected in the collector of each emissary in consecutive inspections. As systems deteriorate over time if no gaps occur in the identification of anomalies or intervention had not been carried out, the number of defects would remain constant or would increase between inspections.

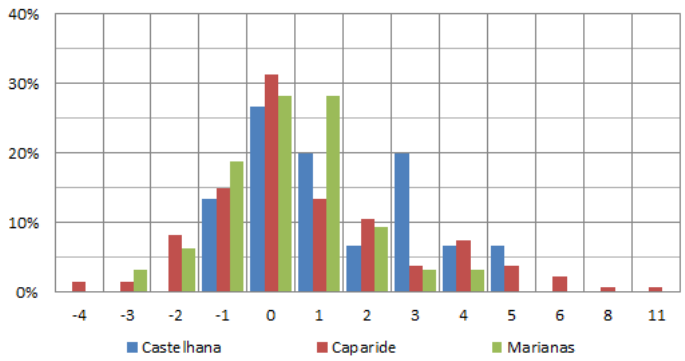


Figure 1- Variation in the number of anomalies identified between consecutive inspections

However, by observation of the graph, differences were negative in all emissaries. The negative difference of one less anomaly between consecutive inspections is the most representative in all emissaries. This occurs in 13% to 18% of the total number of sections each emissary. In emissaries Caparide and Marianas, a negative difference of two anomalies in just over 5% of the sections was observed.

In practice, the inspector uncertainty in the identification of anomalies should be close to the range associated with the negative difference of 1 or 2 anomalies, which corresponds to an uncertainty of approximately 13% and 24%. The cases of negative difference of 3 or 4, in addition to not being significant, are likely to have been motivated by other aspects not related to the inspector.

5.3. Uncertainty of the inspector in the identification of structural defects in collectors

The defects identified in CCTV inspections are usually grouped according to functional defects or structural defects. The structural defects may be openings or offset joints, cracks, breaks and deformation. The classification of structural defects and their severity depends on the material of the collector. The rehabilitation of these defects is generally done by replacing the portion of the collector, substitution of some components like the rubbers of joints or the use of linning technique for coating the collector with a new layer.

Structural defects used in this evaluation correspond to deformations, cracks, fractures, broken collectors, collapse of collectors and displaced joints. More details about the choice of structural defects for this analysis can be found in the master thesis.

On the other hand, the time interval between CCTV inspections, in the same collector, is 4 years. This time interval can be long enough so that there is a worsening of the state of the anomaly in the second inspection and this anomaly may have evolved into another family. To analyze this situation, the families of anomalies were grouped in order to characterize this evolutionary behavior. For these groups the number of anomalies not detected on second inspection was also analyzed. The groups of families considered were:

- Fractures + Broken Collector + Collapse;
- Broken Collector + Collapse;

Table 2 shows the results of the analysis on the percentage of the number of structural defects that were not detected at the second inspection.

Table2- Uncertainty of the inspector in the identification of structural defects in collectors

Anomalies	**Percentage of the number of structural defects that were not detected at the second inspection**			
	Marianas	**Castelhana**	**Caparide**	**Total**
Deformations	14% (2/14)	0%	0%	14% (2/14)
Cracks	46% (6/13)	77%(65/84)	0%	73% (71/97)
Fractures	35% (8/23)	43% (40/93)	100% (3/3)	43% (51/119)
Displaced joint	71% (12/17)	82% (27/33)	35% (8/23)	64% (47/73)
Broken Collector + Collapse	75% (6/8)	38% (5/13)	0%	52% (11/21)
Fractures + Broken Collector + Collapse	45% (14/31)	36% (38/106)	100% (3/3)	39% (55/140)
Total	45% (34/75)	61% (137/223)	42% (11/26)	56% (182/324)

From this analysis it can be concluded that the structural defects of type deformations, despite only having been recorded in the collector of Marianas, are detected effectively by the inspector. Only 14% of the abnormalities were not detected in the second inspection. In general, anomalies like cracks were not detected in the second inspection in 73% of cases. This type of structural defects are likely to be obscured by dirt on the walls of the collector. The displaced joint defect was not detected in the second inspection in 64% of cases. The fractures and the group of families broken collector + collapse presented overall percentages of 43% and 52%, respectively, but when taken together the three types of anomalies (fractures + broken collector + collapse) the percentage anomalies not detected on second inspection is reduced to 39%, indicating that the horizon of four years allows an evolution in the type of structural anomalies. It is possible that an anomaly in a 1st inspection can be identified as a fracture and in subsequent inspection it has evolved into a broken collector or a collapse.

5.4. Impact of uncertainty in the classification of inspector through protocols WRc and NRC

Following the previous analysis, the impact of uncertainty associated with the identification of anomalies when assigning the degree of functional and structural condition through the protocols WRc and NRC was also evaluated.

5.4.1 Functional degree assigned by protocols WRc and NRC

Figure 2 shows the differences in terms of the degree of functional condition of the collectors, between consecutive inspections, according to the approach by the weight average of the anomalies and the maximum weight respectively by WRc protocol. Comparing the proportion of negative differences between the first approach and the second

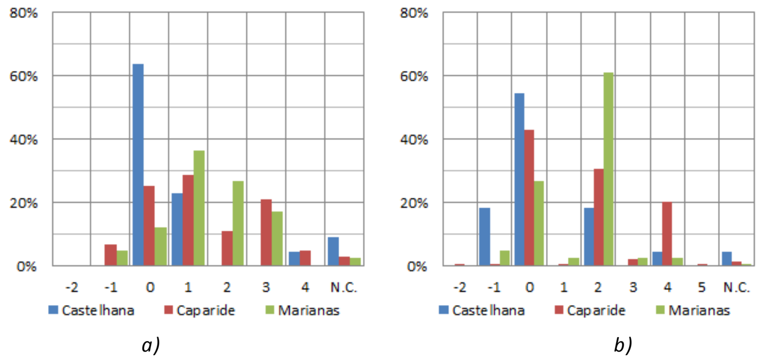


Figure 2- Uncertainty of the funtional degree status according to protocol WRc, using a) the average weight of anomalies and b) the maximum weight .

approach WRc protocol, it appears that the impact of uncertainty associated with the identification of anomalies by the inspector, are less significant in the degree of functional condition of the approach of the average than by the maximum value, for which negative differences were observed in about 18% of the collector Castelhana.

Figure 3 shows the same assessment of the functional condition of the collectors, between successive inspections, but according to the protocol by NRC maximum weight approach.

Using the NRC protocol in the assignment of the functional degree status, only differences one degree negative were observed between consecutive inspections to a limited number of collectors. However, the number of anomalies which contribute to estimate the functional degree by this protocol is much lower than the WRC of the protocol due to the existence of deposits of grease or disengaged sealing rings which were not taken into consideration.

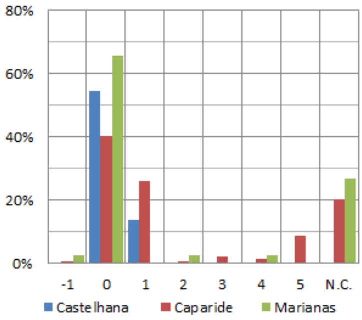
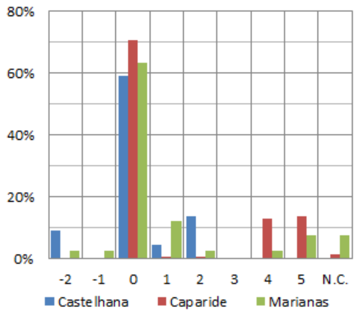


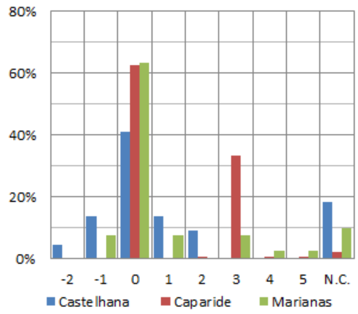
Figure 3- Uncertainty of the functional degree status according to the NRC protocol.

5.4.2 *Structural degree assigned by protocols WRc and NRC*

Figure 4 shows the differences in the degree of structural condition of sewers, between consecutive inspections, according to the WRc and NRC protocols. Following the recommendations of both protocols, the approach to structural classification for both protocols is the maximum weight.



a)



b)

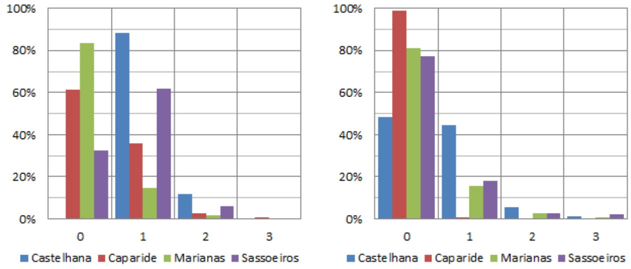
Figure 4- Uncertainty of the structural degree for a) WRc and b) NRC.

In both protocols, negative differences are reduced, indicating that the uncertainty associated with the identification of anomalies by the inspector does not have great influence in determining the degree of structural condition. This result can be explained by the fact that the structural condition are given by anomalies more severe and visible, and therefore more likely to be consistently detected in the inspections.

5.5. Uncertainty in the protocol used

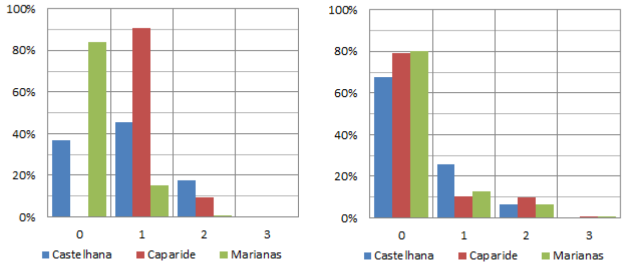
Another source of uncertainty is the protocol adopted. The weights attributed by the protocols to different anomalies are somewhat subjective and it is expected that there will be differences in the degree of condition obtained by different protocols. Additionally, the approach used to determine the weights and the criteria to convert the degree of their condition are also sources of variability. In particular, in the case of assigning the functional degree by the protocol WRc using the approach of the average weight of the anomalies or the maximum value approach can lead to different results between the two approaches.

This analysis was performed for each inspection of emissaries of Caparide, Castilian, Marianas and Sassoeiros.



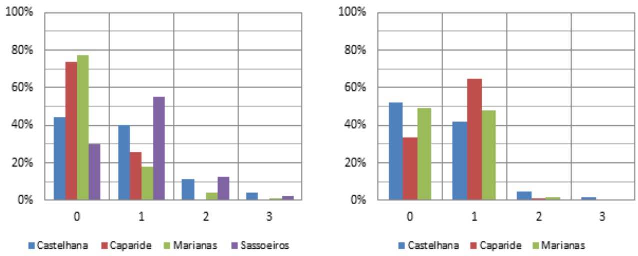
a) b)

Figure 5- Uncertainty of the condition grading between the protocols WRc and NRC for a) functional condition and b) structural condition, in 1st inspection.



a) b)

Figure 6- Uncertainty of the condition grading between the protocols WRc and NRC for a) functional condition and b) structural condition, in 2nd inspection.



a) b)

Figure 7- Uncertainty of functional degree difference between the approaches of the average weight and the maximum weight according to protocol in the WRc) 1st inspection b) 2nd inspection.

5.5.1 Caparide emissary

Applying the protocol WRc to determine the functional degree of the emissary of Caparide, approaches by average weight and the maximum weight have a difference of 1 degree in about 26% of the number of sections of the emissary in the 1st inspection and 62% in the 2nd inspection. This difference is explained by the fact that the 1st inspection to this emissary showed a small number of functional anomalies as compared with the 2nd inspection. The difference in degree between the approaches is explained by the fact that in the approach of the maximum weight, condition grading is based on the most severe anomaly and the collector status is actually the status of the section in which the most severe anomaly is located. In the case of the approach by the average weight, condition of the collector is made based on the weighted average of the anomalies found along the collector, so this approach gives the status of all the length of the collector. (Figure 7).

The difference in the allocation of the degree of functional status between the NRC and WRc protocol is due to a variation in behavior between inspections. On the first inspection it was observed that about 60% of the number of sections of the emissary showed no difference in degree between the two protocols. This behavior is explained by the fact that most sections show no functional defects. In the second inspection, the majority of the sections has functional defects, resulting in variation of the condition in 1 degree in about 90% of the length of the emissary (Figure 5 – a; Figure 6 - a).

The structural evaluation of the emissary denotes that the majority of the sections shows no structural defect in the first inspection, so that about 99% of the sections do not exhibit the degree of difference in structural condition between the two protocols. In the most recent inspection, approximately 80% of the sections still show no difference in the degree of condition, and the differences are rather small, about 20% is shared by variation of 1 degree and 2 degrees (Figure 5 – b; Figure 6 - b .)

5.5.2 Castelhana emissary

The behavior, in terms of variation of the functional degree between different approaches of WRc protocol, is similar in both the inspections to Castelhana emissary. There is no variation in about 43% to 52% of the sections. The most significant variation is 1 degree in about 40% of the outfall sections on both inspections. The variation can again be explained by the conceptual differences of the two approaches (Figure 7).

In the first inspection, the comparison between functional degree between protocols results in the difference of 1 degree in 90%, and is associated with the fact that the WRc assign a higher grade for the anomalies observed. The difference of 2 degrees in 10% of the sections results from the tendency of protocol NRC assign a higher grade when the anomaly "intrusion of roots" is dominant. In the second inspection, the difference of 1 degree between protocols in 45% of the emissary and 2 degrees in 17% of the emissary results of the same reasons (Figure 5 – a; Figure 6 - a).

In comparison between structural degrees attributed by the protocols, most sections on both inspections provide a structural degree greater than zero, which indicates that most of the sections have structural defects. In the first inspection, there is no difference in degree between both protocols in 49% of sections inspected. A difference of 1 degree of this inspection is associated with 45% of the sections and the protocol that assigns a higher grade is the WRc. The remaining differences are not very representative of this inspection. In the second inspection, there was an increase to 68% of sections that do not have differences in the degree of structural condition. This increase from inspection to inspection seems to indicate that the degradation of the anomalies over time leads to the degree assigned by the NRC tending to equalize the level assigned by the WRC. The other categories of difference in the structural degree between protocols are significant (Figure 5 – b; Figure 6 - b).

5.5.3 Marianas emissary

In the first inspection, the different approaches of the WRc protocol for functional classification in Marianas emissary shows no differences of degree in about 78% of the sections of the emissary, the variation of 1 degree is the most common and occurs in about 18% of the sections. The variation of 1 degree between approaches in the second inspection is higher, about 47% of the sections. In the most recent inspection, there is no variation in about 49% of the sections and the 2 degree variation is present in about 4% of the sections. This difference in behavior between inspections is justified by the increase of functional defects between inspections, and in the first inspection the number of functional defects was reduced. Again, the differences can be explained by the conceptual differences between the approaches (Figure 7).

About 13% of the sections of the emissary have a difference of 1 degree in functional evaluation in both the inspections and, as in other emissaries, this behavior is in most cases caused by the WRc protocol assigning a higher level than the NRC protocol (Figure 5 - a Figure 6 - a).

In the structural evaluation, it is observed that in both inspections the majority of the sections don't have any associated structural defects, thus there is no difference in the degree of structural condition for almost the entire length of the outfall (Figure 5 - b Figure 6 - b .).

5.6. Sassoeiros emissary

The sections of the collector of Sassoeiros have more functional defects. The difference of one degree between the approaches by average weight and the maximum weight of anomalies is more pronounced in this emissary, affecting about 53% of all sections of the emissary. These differences can also be

explained by the conceptual difference in method to assign functional degrees to the collectors by the two approaches. (Figure 7).
The difference of 1 degree in functional condition between protocols is present in 60% of the sections. This result is a consequence of the WRc protocol assign a higher level than the NRC protocol. In this analysis, it is worth noting that 30% of the emissary sections show the same degree of functional status for both protocols (Figure 5 - a Figure 6 - a).
Two of the most used materials in the sections of this emissary are PVC and PVC-C, representing about 27% of the sections of the outfall. The years of construction of sections with these materials are between the years of 2000, 2005 and 2007, which is normal to register a few structural defects. This contributed to the fact that there were no differences of degree in structural condition in about 77% of the emissary (Figure 5 - b Figure 6 - b).

6. CONCLUSIONS

The evaluation of the condition of the collectors and the decision on the type of rehabilitation to be performed are important processes for the establishment of a proactive strategy in order to improve the performance of drainage systems. In this thesis, the evaluation of the condition of the collectors was conducted by WRc and NRC protocols. Comparing the classification of the sections obtained by the two protocols it should be noted that the protocol WRc generally tends to assign more severe ratings than the NRC protocol for both functional and structural classification. . In the case of the WRc protocol, it should be noted that this protocol allows the assignment of the functional condition according to two approaches, one by the average weight of the anomalies found in the section of the collector and the other approach based on the weight of the most severe anomaly found in the section. The approach by the maximum weight of the anomalies represents a better location where the collector is more degraded and the approach of the average weight better represents the overall status of the collector. It is recommended to use both approaches to determine the functional status of the collector, because in a situation when it is useful to know the condition of some part of the infrastructure, having both classifications allows the technician to know the general state of the section, as well as the state of the zone where the most severe anomaly is located.
Another important process in implementing a proactive strategy is the inspection of drainage infrastructure. In the case study the inspection of the infrastructure is performed by CCTV technique. The uncertainty associated with this technique is due to the limitations explained in subchapter 5.1. The analysis of the uncertainty of the CCTV inspector in identifying anomalies in collectors reveals that the error associated uncertainty is still significant. Comparing with the study of DIRKSEN et al. (2007) where about 30% of a first inspection identified anomalies were not detected in the subsequent inspection, the values in our analyses were higher, 56% of the anomalies were not detected in the subsequent inspection. In the analysis of uncertainty of the inspector in the identification of structural defects in collectors (subchapter 5.3), the sample of anomalies was reduced, then the uncertainty values associated with the identification of each structural anomalies were not representative enough to draw conclusions about the efficiency of the inspector in identifying them. It is recommended that in future studies the analysis is carried out again with the inclusion of data from other collectors allowing the expansion the sample.
Despite the uncertainty of the inspector to identify defects is significant to evaluating the condition of the collectors using protocols, subchapter 5.4 analysis shows that errors arising from the inspector do not affect the functional and structural classification of the collectors. These results are explained by the fact that the most severe anomalies are generally detected by the operator in consecutive inspections and these anomalies will be more relevant to the assignment of the classification section.
The use of inspection data for decision-making and application in prediction models based on deterioration process should be undertaken with caution, as the error associated with the inspector is still significant. For the development of deterioration models, which could be a topic for future research, it should be used if the condition of the collectors assigned by protocols as they reflected less the error associated with the uncertainty of CCTV inspections.

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