

Urban Flooding: Improvement of Pluvial Drainage System against Saturations on Rondeau Avenue in Paraná

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Summary— Paraná has street flooding problems which arise during abundant rainfalls due to poor urban drainage systems. The focus of this study is a specific section of Rondeau Avenue which frequently experiences street floodings. The purpose of this presentation is to address the urban flooding problem on Rondeau Avenue in Paraná. This can be done by achieving an efficient urban drainage system that meets current and future requirements. This involves the improvement of the poor stormwater drainage system maintenance and the incorporation of storm retarders. This work is structured as follows. First, the description of the context provides a brief description of Paraná city, the area where the problem is located and the points of interest around this area. After that, the persistent flooding problem experienced on Rondeau Avenue is addressed. Next, there is a description of some scenes that help picture the problematic situation. Then, the causes of the problem as well as its consequences are analyzed. The following section focuses on the Problem Approach which offers an effective and feasible engineering solution. Finally, the main strengths and weaknesses of this proposal are examined. Through this work, we expect to provide an overview of the problem that affects a section of Rondeau Avenue, with the objective of raising awareness about this situation which impacts the neighbor's daily life and it often lacks proper visibility. Moreover, we want to address the problem by providing an innovative solution that can serve as a blueprint for solving other similar cases in the city as well.

Keywords: cleaning, flooding, storm drains, street.

Resumen— Paraná tiene problemas de inundaciones en las calles, que surgen durante lluvias abundantes debido a sistemas de drenaje urbano deficientes. Este estudio se enfoca en una sección específica de Avenida Rondeau, que frecuentemente experimenta inundaciones. El propósito de esta presentación es abordar el problema de las inundaciones urbanas de Avenida Rondeau en Paraná. Esto se puede realizar logrando un sistema de drenaje urbano eficiente que cumple con los requisitos actuales y futuros. Esto implica la mejora del deficiente mantenimiento del sistema de drenaje pluvial y la incorporación de retardadores de tormenta. Este trabajo está estructurado como sigue. Primero, la descripción del contexto proporciona una breve descripción de la ciudad de Paraná, la zona donde se ubica el problema y los puntos de interés alrededor de la zona. Después de eso, se aborda el persistente problema de inundaciones experimentado en Avenida Rondeau. A continuación, está la descripción de algunas escenas que ayudan a visualizar la situación problemática. Luego, se analizan las causas del problema, así como sus consecuencias. La siguiente sección se centra en el enfoque del problema, que ofrece una

solución de ingeniería efectiva y factible. A través de este trabajo, esperamos brindar una visión general del problema que afecta una sección de Avenida Rondeau, con el objetivo de generar conciencia sobre esta situación que impacta la vida cotidiana de los vecinos y a menudo carece de una visibilidad adecuada. Además, también queremos abordar el problema proporcionando soluciones innovadoras que puedan servir como un modelo para resolver otros casos similares en la ciudad.

Palabras clave: limpieza, inundaciones, drenajes pluviales, calle.

I. INTRODUCTION

This work tackles a problem that the city of Paraná has related to the urban drainage system which arises during abundant rainfalls. This is due to the fact that the drainage system has a poor performance so it generates high runoff flows. This situation often results in road overflow. The focus of this study is a specific Avenue which is located in the northeast sector of Paraná city. This street serves as an inlet and is a section of Rondeau Avenue, situated between Fraternidad Street and Raúl L. Uranga Avenue.

The purpose of this presentation is to address the urban flooding problem on Rondeau Avenue in Paraná. This can be done by achieving an efficient urban drainage system that meets current and future requirements. This involves the improvement of the poor stormwater drainage system maintenance and the incorporation of storm retarders, which are physical devices that are designed to facilitate the collection, temporary retention and controlled discharge of water.

This work is structured as follows. First, the description of the context provides a brief description of Paraná city, the area where the problem is located and the points of interest around this area. After that, the persistent flooding problem experienced on Rondeau Avenue is addressed. Next, there is a description of some scenes that help picture the problematic situation. Then, the causes of the problem as well as its consequences are analyzed. The following section focuses on the Problem Approach which offers an effective and feasible engineering solution. Finally, the main strengths and weaknesses of this proposal are examined.

Through this work, we expect to provide an overview of the problem that affects a section of Rondeau Avenue, with the objective of raising awareness about this situation which impacts the neighbors' daily life and it often lacks proper visibility. Moreover, we want to address the problem by

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providing an innovative solution that can serve as a blueprint for solving other similar cases in the city as well.

II. PROBLEM DEFINITION AND ANALYSIS

A. Description of the Context

The province of Entre Rios is one of the 23 Argentine provinces and its capital is Paraná city. It has a population of 280,087 people according to the 2022 Census.

Next to the capital city is the Paraná River. It is the most important river in Argentina and one of the most important in the South American continent in terms of flow and length.

The Paraná River receives a significant amount of water. Only in this city there are at least 13 streams which flow into it (Fig. 1). In this way, there is a surface of 137 Km² which is divided into 13 basins.

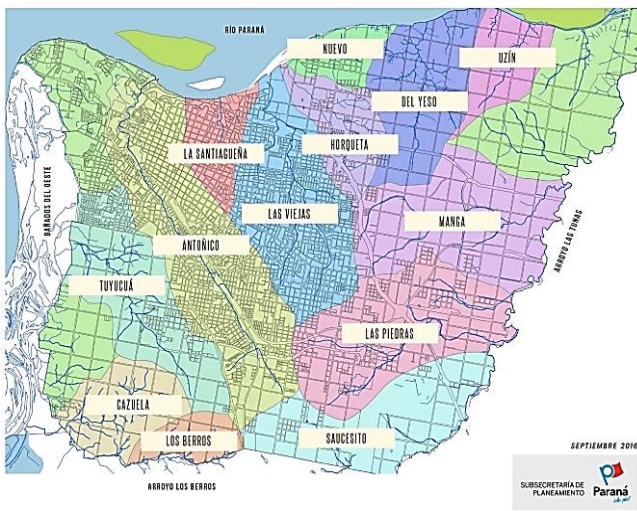


Fig.1. Map of basins in Paraná city.

In the north of Paraná is Las Viejas stream and its important basin which has a surface of 12,3 Km². There are some points of interest in this zone of the city as the National Technological University on Almafuerte Avenue which is an important engineering university (Fig. 2). Another distinguished construction is the Presbítero Bartolomé Grella Stadium of the Atletico Patronato Club.



Fig.2. View of the National Technological University.

In Fig.3 it can be seen that in the northeast of the city is Rondeau Avenue, which is the street analyzed in this work.

To the east, there is Police Station 14 and the Air Division of the Entre Rios Police; to the west, there is the final stretch of Colorado Stream. In the north, we have Circunvalación José Hernández Avenue, where Raúl Humberto Zaccaro High School and Paraná Rowing Club Tortuguitas Headquarters are located. To the south, there is the Police School of Entre Rios on Fraternidad Street. In this zone, there are a few houses, some stores and all streets are paved.



Fig.3. Rondeau Avenue district.

In Fig. 4, behind the Police Station 14, there is the police heliport with its respective landing strip and its hangar. On the left side of the photo, there are also the homes of the first residents of this neighborhood in Paraná which is called Altos del Paraná.



Fig.4. Section of Rondeau Avenue.

In Fig. 5, on Rondeau Avenue, some shops can be seen, such as this greengrocer. In the background, there is the training ground of Salvador Maciá Police Officers' School and the Police Clinic, which was inaugurated three years ago.

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Fig.5. Another view of Rondeau Avenue.

B. Problem Statement

The problem under analysis is about a section of Rondeau Street stretching between Fraternidad Street and Uranga Avenue. When rains occur, water flows along both edges of the street but, after a short period of time, it overflows the drainage capacity, reaching up to the sidewalk. This situation becomes critical when addressing points of higher intensity rainfall. At such times, the water level rises to the point where it inundates both lanes, and in some instances, breaches the edges.

This analyzed section of Rondeau Avenue measures approximately 340 meters. It serves as a transitional pathway between the elevated area of Fraternidad Street and the lower zone of Uranga Avenue. Covering these two zones there is a seven-meter elevation difference, so the lengthwise slope of the street is important. Moreover, the rainwater drainage system consists of ten sumps, as indicated in Fig.6.

Even though it has already been mentioned that the level adjacent to Fraternidad Street is higher, Rondeau Avenue also receives water runoff from other elevated streets when it rains. These include Dr. Maradona Street, Ciudad Hermana de Muscatine Street, Segismundo Satullosky Street and Pasaje Catalonia Street.

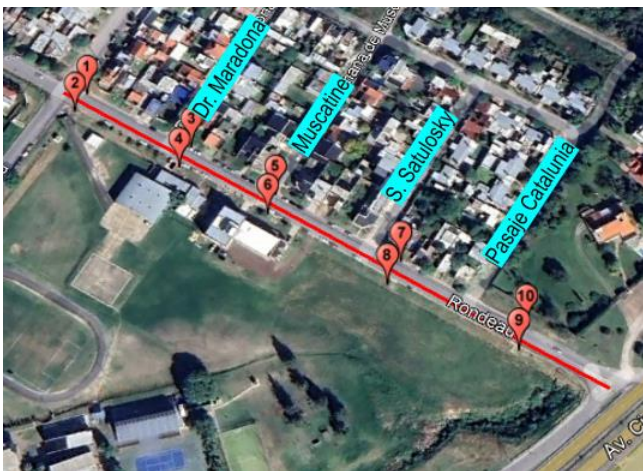


Fig.6. Location of sumps.

C. Description of Scenes that Help Picture the Problematic Situation



Fig.7. View of an inundation on Rondeau Avenue.

As can be observed in Fig.7, on a heavy rainy day, the street is overflowed from side to side and also advances onto the edges of the sidewalk. To the right of Fig.7, you see a parked car near the curb. Another car passed by a few minutes earlier, causing the water on the left side of the photograph to form waves.



Fig.8. Flooding at the end of Rondeau Avenue.

In Fig.8, you can see the water flowing from east to west, following the direction of the North Access Route. On the right side of the image, you see that the water level from the sidewalk reaching from side to side. Drains or storm drains cannot cope with the volume of this flow.

In the background of the photograph, it appears that the water is attempting to flow on the route. The street is 12 meters wide and the sidewalk extends up to the boundary of the Police School, covering 4 meters wide. Cars must circulate very carefully so as to avoid any risk caused by the sediments brought by the water's current.



Fig.9. Sediments in the curve to Uranga Avenue.

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In Fig.9, you can see that there is a lot of dirt accumulated on the asphalt of the street after rainfall. Also, there is much more sediment on the edges of the curb, and there is a layer of soil between the middle and the edge of the street.

D. Identification and Analysis of Causes or Factors that Give Rise to the Problem

Several causes of this problem can be named. One reason for this situation is the poor maintenance of the stormwater drainage system. When precipitation occurs, water flowing over the road carries sediment and dirt. This cumulative effect has become significant over time. The Municipality of Paraná, which is the entity in charge of cleaning these storm drains, has not carried out the minimum maintenance necessary for their correct operation over the years. This has caused the clogging of three out of ten storm drains, specifically those closest to Uranga Avenue.



Fig. 10. View of a clogged storm drain.

Another cause is related to the incorrect design of the stormwater drainage system. Storm drains must be designed under certain guidelines related to hydrology and engineering. The type of storm drain used in this area is known as a curb opening inlet [1], and its operation is optimal when the longitudinal slope of the road does not exceed 3%. In the case of the area under study, there is a central area an inclination of approximately 5%, so two out of nine storm drains found in this area probably function poorly.



Fig.11. Elevation profile of the street.

The obsolescence of the drainage system due to urban development over time is another cause that can be mentioned. Based on a hydrological study of a region, it can be concluded that storm drains are designed to handle a specific water flow. As the built-up area of a region expands over time, there is less surface area available to absorb precipitation and, therefore, there is a decreased water runoff. The entire sector under study has suffered a large increase in its built-up area in recent years, which can be seen by comparing Fig.12 (year 2002) with Fig.13 (year 2023). This expansion has caused stormwater drainage system to become practically inoperative.



Fig.12. View of the sector in 2002.

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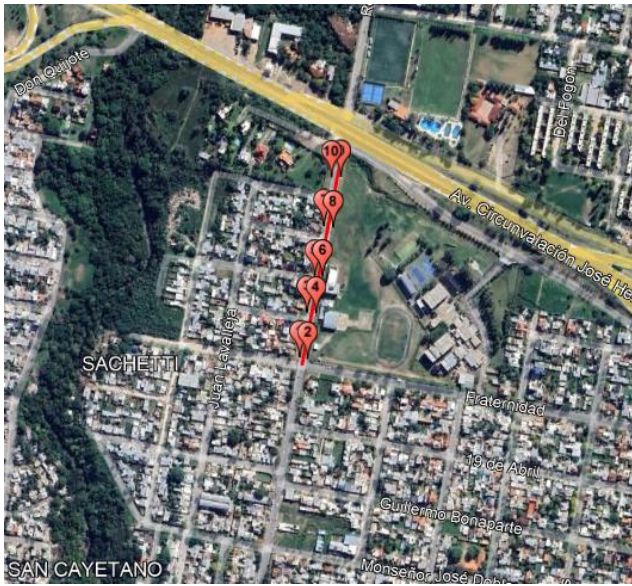


Fig.13. View of the sector in 2023.

E. Identification and Description of the Consequences

There are different consequences related to the flooding of this road. The main consequence of this situation is the risk that this causes in vehicular and pedestrian safety. The flow of water produces a great thrust, generates a lack of grip between the pavement and the tires and impedes visibility of the road, so vehicles maneuver with difficulty and run the risk of accidents. Moreover, the vehicles often become stranded, obstructing traffic on the Rondeau Avenue. Since there are no sidewalks on both sides, pedestrians risk being forced to walk on the street.

Another consequence has to do with the existence of a risk of skidding for vehicles that travel along the junction curve between Rondeau Avenue and Uranga Avenue. As mentioned before, a large water puddle is formed at this locations and persists for approximately two days after the precipitation. This causes, specifically in this place, a risk of skidding for vehicles that take the curve. In addition, this flooding fosters the breeding of mosquitoes that transmit dengue.

Finally, we can highlight that floods gradually cause cracks in the pavement. Moreover, the growth of existing cracks due to traffic, make the useful lifespan of the asphalt layer progressively diminish.



Fig.14. Roadway deterioration and repairs.

III. THE WAY FORWARD

A. Problem Approach

The urban flooding problem on Rondeau Avenue requires a two-step approach to be addressed. In the first place, it is essential to incorporate the pluvial retarders. A pluvial retarder is a hydraulic device which is used to retain a volume of water while a heavy rain is occurring and it discharges it through a drain pipe. These reservoirs serve to decrease the maximum flow and to extend the duration of water entering the drain network, in such a way floodings are prevented [1].

The reservoirs are basically underground chambers that are located under the sidewalk and connected directly to the storm drains and to the drain network's pipelines. They have prismatic shape and are divided into two compartments, as it can be seen in Fig.15. They can be built in-situ using reinforced concrete or using prefabricated concrete panels.

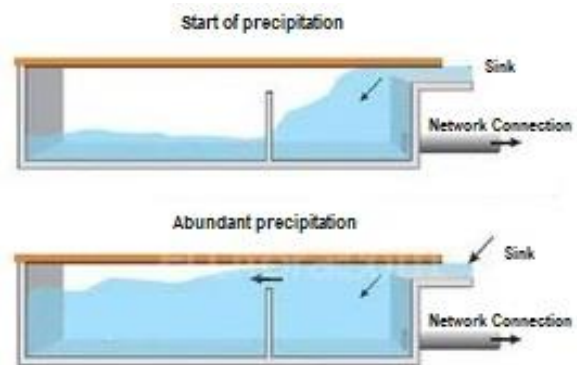


Fig.15. Reservoir functioning. [2]

To implement this solution, the sidewalk area next to each sinkhole must first be excavated down to the level of the pluvial drain pipe, as well as the underground service installations that may interfere should be relocated. After this, prefabricated concrete panels must be mounted in order to build the reservoirs. This process must be carried out for all the sinkholes in the sector. Fig.16 shows a system sketch for sinks 7 and 8.

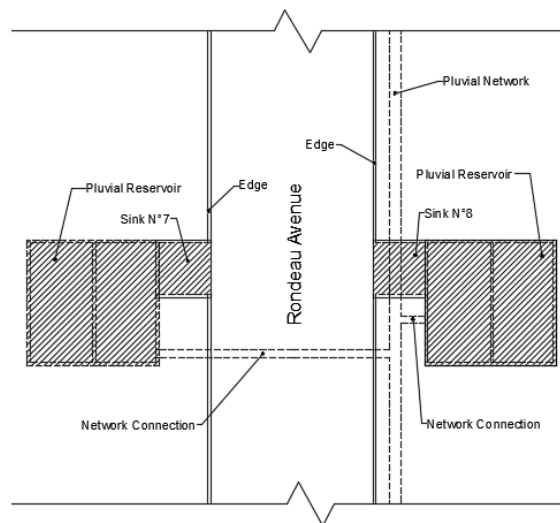


Fig.16. Sketch of a system part on Rondeau Avenue.

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In the second place, the maintenance service must be considerably improved. Nothing will work out properly if the periodic cleaning of storm drains is not thoroughly done by the competent entity, the city's municipality. This service must focus mostly on sinks number 5, 7 and 10 because of their small dimensions. In the case of sink number 10, a complete-unclogging must be done.

B. *Strengths and Weaknesses of the Proposal*

This section evaluates the main strengths and weaknesses of the proposal for addressing this issue. The main advantage that can be attributed to this proposal is its practicality, the construction process simply includes excavation in specific places and the assembly of remodeled pieces. In other words, it is a low-complexity work that does not interfere much with the daily life of the neighbours. Otherwise, the replacement of the entire pipe would imply breaking into the entrances to the homes, and the pavement. In addition, it is a durable solution, which is able to cope with rainfall if it increases in the future.

As negative consideration, we can mention the costs. The expenses associated with the consequences of flooding, such as street cracks and accidents are reduced and maintenance costs are not relevant. However, the main investment that

must be made for this improvement pertains to the volume of land to be excavated, the shoring work to be carried out, as well as the relocation of the service lines.

IV. CONCLUSION

The flooding problem in the section of Rondeau Avenue that has been analyzed affects an important percentage of the neighborhood's population. It is an important artery because it is an entry point to the city and connects to some points of interest. The lack of maintenance and the obsolescence of the drainage system have caused it to operate poorly so the road floods on heavy rain days, which in turn results in pavement deterioration and safety risks for users. The reservoir's incorporation and the maintenance service improvement grant a feasible and economically reasonable engineering solution.

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The present project is a skills integration activity in Inglés I at Universidad Tecnológica Nacional, Facultad Regional Paraná, carried out by EFL engineering students. The yearlong project requires students to delve into a problem in the city where they live and to address it by means of a simple project in English. Should the reader have any questions regarding this work, please contact Graciela Yugdar Tófalo, Senior Lecturer, at gyugdar@frp.utn.edu.ar.