Trenches drainage – Final Report

October 2017

Revision	Date	Elaboration Responsible	Approval Responsible	Comments
0	16/10/2017			Initial version
1				
2				
3				

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1. Introduction

Railway Project will have two reaches of railway in the form of trenches in urban areas in order not to interfere with traffic. These will be one reach in Montevideo between Carnelli and Yatay Stations, and one in Las Piedras City as can be seen in Figure 1-1 in thick yellow colour.

The consultant was asked to perform the hydrological and hydraulical studies in order to provide the necessary infrastructure to drain rainfall coming directly into the trenches, and surface runoff from urban areas not coming into the trenches.

Figure 1-1 Location of two trench reaches

Rainfall coming directly into trench is drained with lateral conductions when there is slope, towards trench sag point where it could be pumped or connected to other drainage systems such as municipal drainage infrastructure or natural streams. In this sense the consultant was provided with the projected railway elevations presented in Figure 1-2, Figure 1-3 and Figure 1-4.

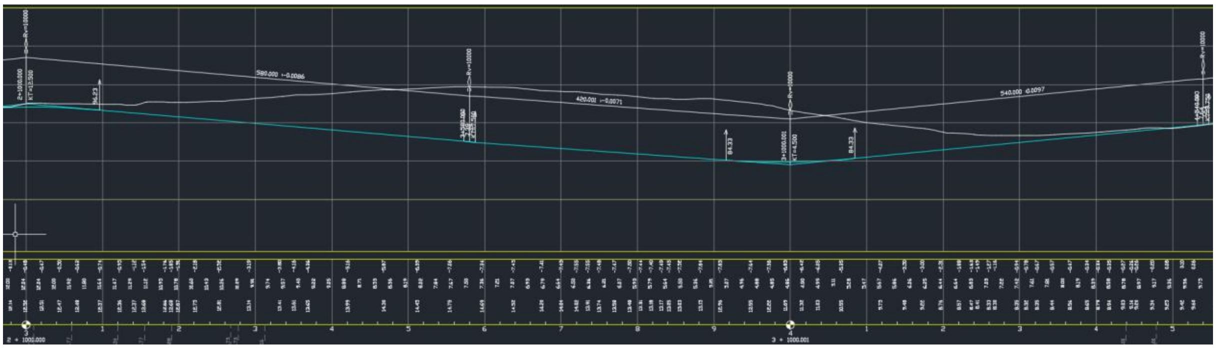

Figure 1-2 Trench elevation profile, Montevideo reach

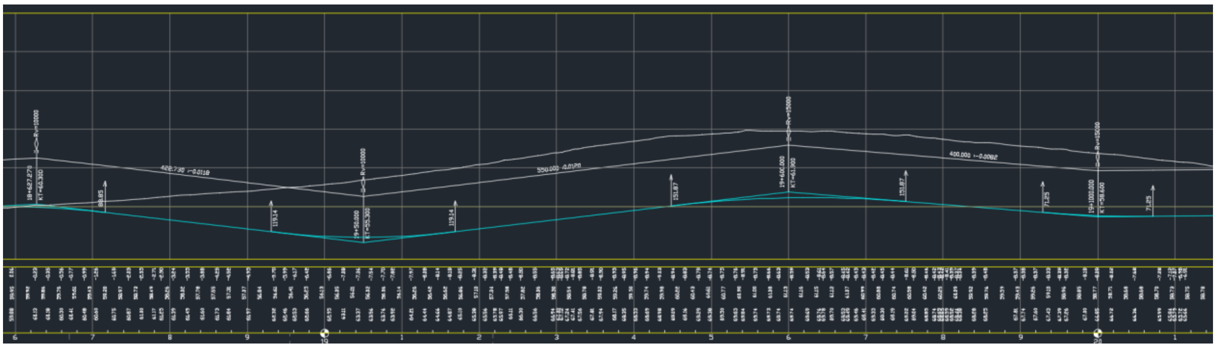

Figure 1-3 Trench elevation profile, South Las Piedras reach

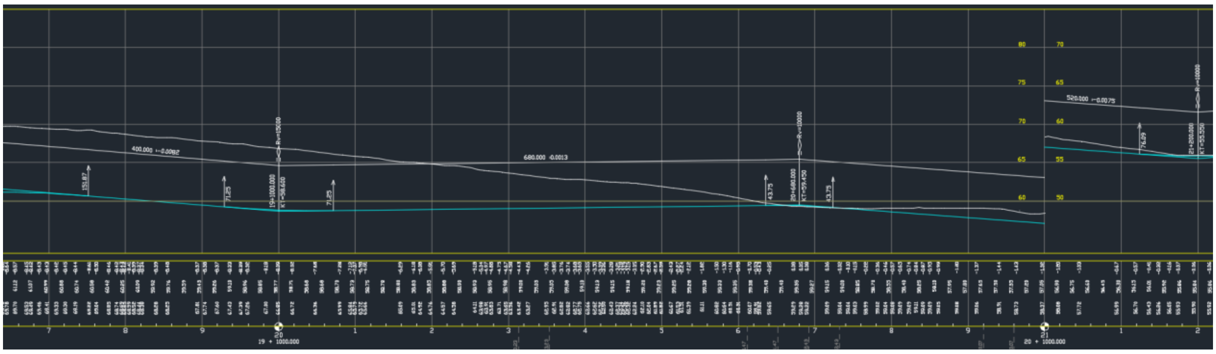

Figure 1-4 Trench elevation profile, North Las Piedras reach

The consultant was also provided with the typical trench cross section, presented in Figure 1-5, in order to provide dimensions for trench and surface runoff drainages.

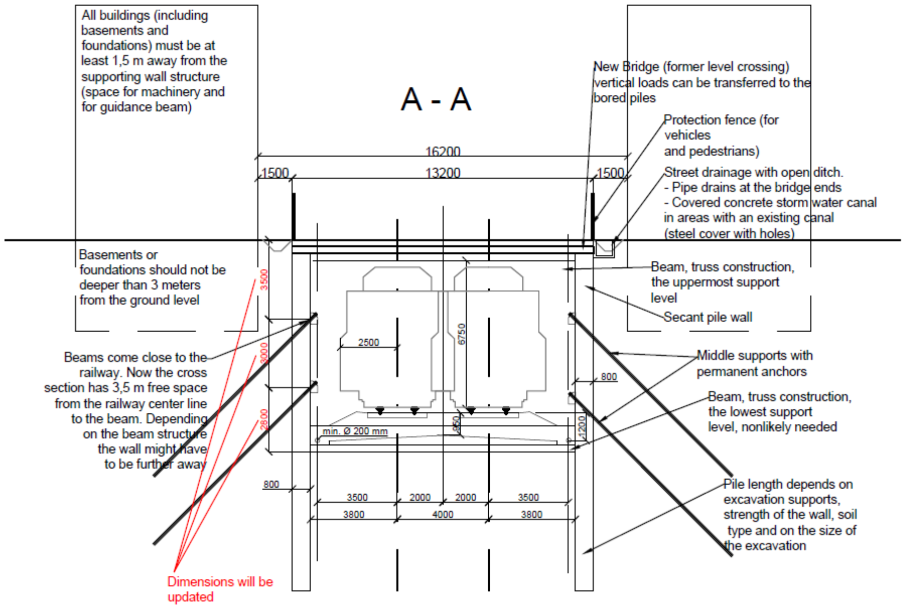

Figure 1-5 Trench typical cross section

Runoff from urban surface is intercepted by channels before trench in order runoff not to come into the trench.

Hereafter, objective of study is presented, then methodology, main results and preliminary conclusions.

2. Objective

Calculate necessary infrastructure to prevent flood risk at railway trench reaches.

3. Information used

- Railway elevation profiles
- Digital Terrain Model (DTM) RENARE MGAP
- Level contours equidistant 2 meters
- Montevideo City Council conduits, inlets and manholes information
- Canelones City Council existing drainage systems information
- Google Street View ™

4. Methodology

All calculations were done considering events of 25 years return period, which is considered appropriate for the railway to protect and the assets being designed.

Drainage of trenches is divided in two, drainage of the adjacent surface areas in order that no water comes into the trench and also the drainage of the rain falling directly into the trench. Nevertheless these two systems might be connected if for example rain falling into the trench is conducted towards low points in elevation profile and from there is pumped to surface and connected to the surface interceptors channels.

4.1. Rain falling in trench

In order to drain rain that comes directly into trench, when there is slope available (grade) drainage is done by longitudinal lateral conductions such as underground pipes or open ditches, when these arrive to the relative low point of trench (sag) they require connecting it to other drainage system by gravity if possible or with pump stations.

4.2. Urban runoff not into trench

In order to prevent urban surface runoff coming into trench, superficial trench ditches or open channels are calculated to intercept these flows before falling into the trench, and they are conducted towards natural streams when trench elevation meets ground elevation.

5. Results

5.1. Rain over trench

Rain over trench divides at the centre axis and half goes to one side and other half to the other as can be seen in the typical cross section presented in Figure 5-1.

When the railway has slope or grade, the trench is drained by to lateral conducts at each side, could be underground pipes or open channels. Once these conduits arrive to low or sag points they discharge into pump sumps which pump flows towards the superficial trenches channels.

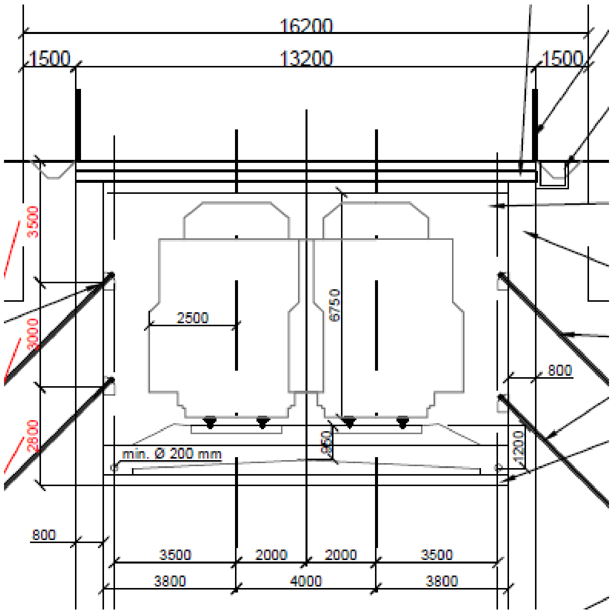

Figure 5-1 Trench typical cross section

5.1.1. Grade

5.1.1.1. With underground pipes

Table 5-1 Underground pipes in Trench 1 in Montevideo

PK	Railway Elevation	Partial length (m)	Elevation diff. (m)	Partial slope (m/m)	Catch. Area (m^2)	Q (m^3/s)	Diam (m)	y (m)	y/D	Vel (m/s)
3000	12.04									
4000	4.86	1000	-7.18	-0.007	6600	0.35	0.6	0.40	0.67	1.7
4540	9.98	540	5.12	0.009	3564	0.19	0.4	0.28	0.70	1.7

Table 5-2 Underground pipes in Trench 2 in Las Piedras

PK	Railway elevation	Partial length (m)	Elevation diff.	Partial slope (m/m)	Area (m^2)	Q (m^3/s)	Diam (m)	y (m)	y/D	Vel (m/s)
18627	59.86									
19050	56.02	423	-3.84	-0.009	2790	0.15	0.40	0.29	0.73	1.54
19600	61.13	550	5.11	0.009	3630	0.19	0.50	0.28	0.57	1.66
20000	58.77	400	-2.36	-0.006	2640	0.14				1.23
20680	59.35	680	0.58	0.001	4488	0.12	0.60	0.35	0.63	0.58
21200	55.84	520	-3.51	-0.007	3432	0.18				

Maximum pipe size needed would be 600 mm inner diameter.

5.1.1.2. With open channels

In case implementing drainage with lateral open channels maximum open channel needed would be a rectangular channel with 0.60 m width and 0.45 m height.

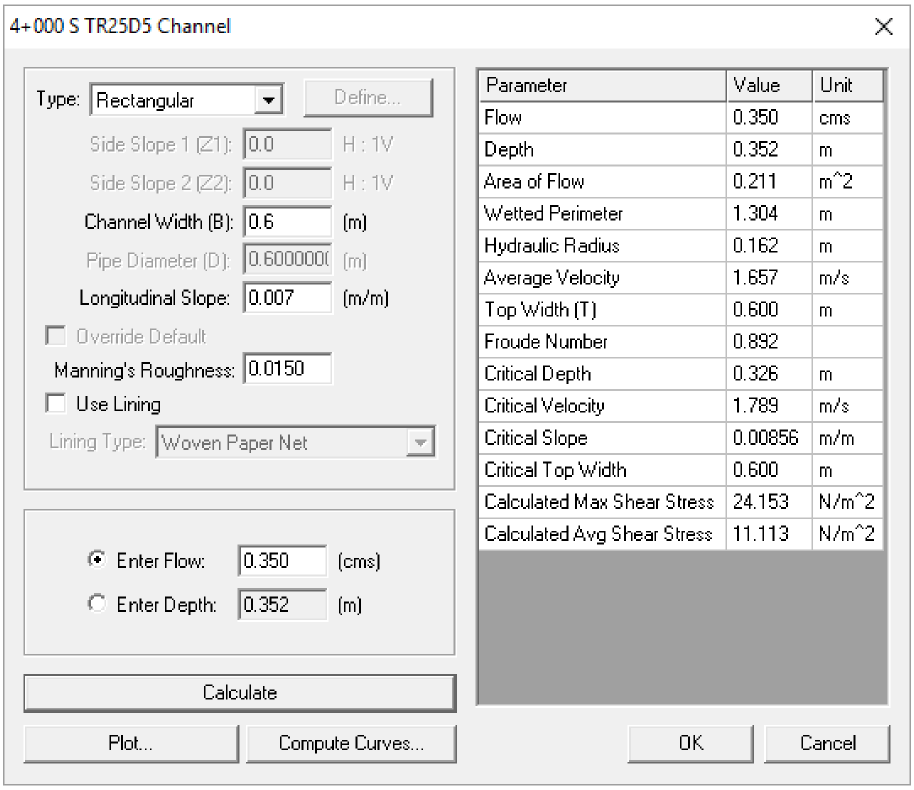

Figure 5-2 Open channel maximum section

In case profile alignment would be deepen from 20+000 to 20+700 in order not to have a sag point at 20+000, the required dimensions for that channel would be 0.60 m width and 0.52 m height.

5.1.2. Sag

5.1.2.1. Sag at 4+000

Flow arriving to sag 4+000 is expected to be 1.1 m^3/s.

Railway Elevation = +4.86 m

Ground Elevation = +11.69 m

Depth = 6.83 m

a) With gravity pipe connection

Nearest water body is Miguelete stream.

Estimated Miguelete stream flood level at railway bridge cross section for 10 years return period is +5.90 m Wharton, which is +4.99 m Official zero.

As water at sag point will be lower than railway elevation of + 4.86 m Official zero, it means if we connect sag point to Miguelete stream there is risk of being flooded by it.

b) With pump station

With a pump station flow at sag point can be connected to an existing drainage system or to superficial trench ditch interceptor.

b1) Towards existing drainage system

Nearest drainage system is municipal drainage with pipe at Uruguayana Street, and manhole number 127016 at Uruguayana Street between Enciso and Gomez streets. Invert level is +8.68 m Wharton or +7.77 m official zero. Pipe is an egg shape 0.8 m width and 1.2 m height, with a pipe full capacity of 2.2 m^3/s. Even though pipe full capacity is greater than pump flow, this option requires checking with municipality if pipe is able to handle this flow, as it conveys also other parts of city.

b2) Towards superficial trench ditch

This option pumps towards trench ditch at ground level, which will convey flows towards Miguelete stream in addition to surface water coming into it. Seems to be the better solution, will need to pump at least depth of sag point of 6.83 m.

5.1.2.2. Sag at 19+050

Flow arriving to sag 19+050 is expected to be 0.7 m^3/s.

Railway Elevation = +56.02 m

Ground Elevation = +63.56 m

Depth = 7.54 m

a) With gravity pipe connection

There is not near water body where to connect and convey flows by gravity.

b) With pump station

Existing drainage systems are the two lateral ditches at each side of railway which will be replaced by designed trench superficial ditches. It is better to connect them to the West side ditch as it has smaller catchment than East one. Geometrical elevation will be at least sag depth of 7.54 m.

5.1.2.3. Sag at 20+00

Even though a proposal of removing this sag point by extending railway slope towards km 21+200, depth at 20+680 will conflict with existing stream at that location. Hence, sag point should be maintained.

Flow arriving to sag 20+000 is expected to be 0.8 m^3/s.

Railway Elevation = +58.77 m

Ground Elevation = +66.85 m

Depth = 8.08 m

a) With gravity pipe connection

There seems to be a municipal drainage channel nearby at 25 de mayo street, and sag point might be connected to it at Canelones and 25 de mayo corner, but there is not elevations information about that channel, at first sight it seems very difficult to achieve connection at this points with a 230 m pipe under existing concrete street. Further studies should be done.

b) With pump station

With a pump station flow can be connected towards existing drainage system with channels that convey railway culverts at Wilson Ferreira Aldunante Street towards the aforementioned channel system, or to the trench superficial ditch. In both cases pump head will be at least the geometrical of the depth of sag of 8.08 m.

b1) Towards existing drainage

Channels at Ferreira Aldunante Street could perhaps be used as conveying system for this sag point. There is no information regarding this channels, further studies should be carried.

b2) Towards trench superficial drainage

Another possibility is connecting pumped flows to the trench superficial ditch which will convey them towards Colorado stream at km 20+680.

5.2. Urban runoff not into trench

5.2.1. Trench 1 in Montevideo

Trench 1 is between chainages 3+000 and 4+540, approximately between Carnely and Yatay Stations as can be seen in Figure 5-3.

From the hydrological point of view the reach is between Miguelete (North) and Quitacalzones (South) Streams as shown in Figure 5-4. Quitacalzones nowadays is completely underground and what can be seen in the Figure is the CSOs pipe of that urban catchment.

In Figure 5-5 and Figure 5-6 the trench reach is presented over DTM and 2 m equidistant elevation contours in order to assess topography at the place. It can be seen there is a high terrain point between the two streams obviously.

With the aid of DTM, contour levels, inlets and conduits information, and Google Street view detailed sightseeing of the area subcatchments which can contribute surface runoff towards the trench were identified, delineated and presented in Figure 5-7.

This trench is in a combined sewers area of the city of Montevideo, which means there are several inlets and pipes, as presented in Figure 5-8, to convey urban runoff so not much surface runoff is expected to arrive near the trench. Furthermore, as trench reach is in a relative high elevation area between Miguelete and Quitacalzones streams, and topography shows that slopes that could convey water towards the trench are limited.

This case could be split in two, as chainage 3+580 is the highest point of railway elevation profile. Trench South of chainage 3+580 is in an area that drains towards Quitacalzones stream, and North part drains towards Miguelete stream.

Figure 5-3 Location of trench reach in Montevideo between Carnelli and Yatay Stations

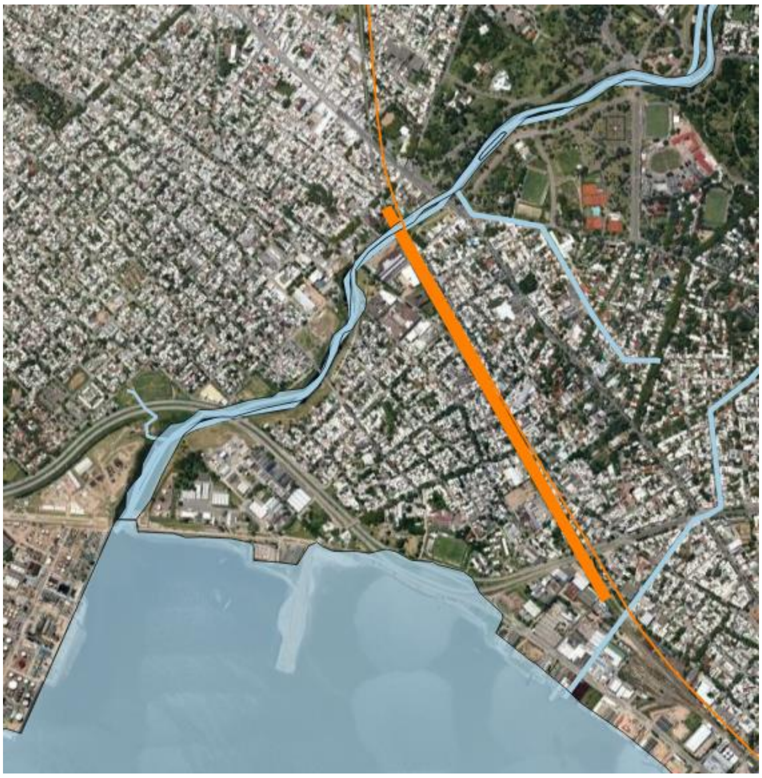

Figure 5-4 Trench reach in Montevideo and nearest streams

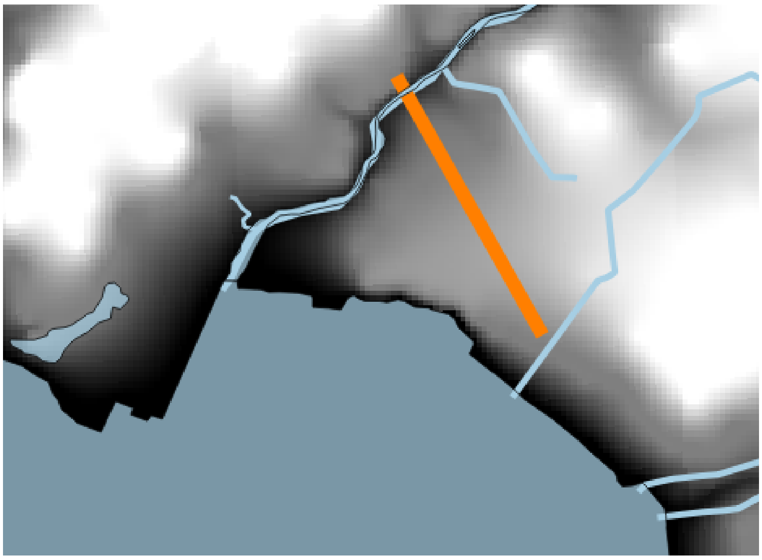

Figure 5-5 Trench reach in Montevideo, streams and DTM

Figure 5-6 Trench reach in Montevideo, streams and level contours

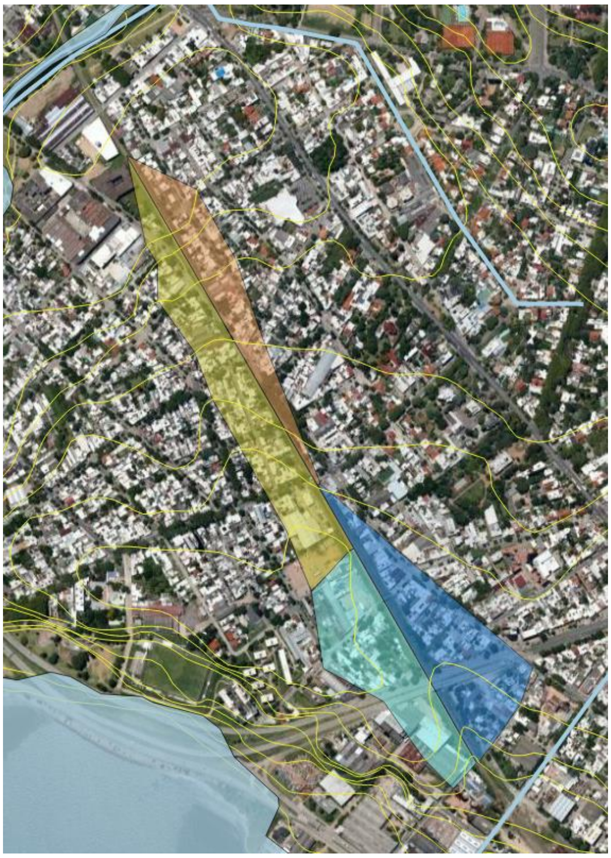

Figure 5-7 Montevideo trench surface runoff catchments

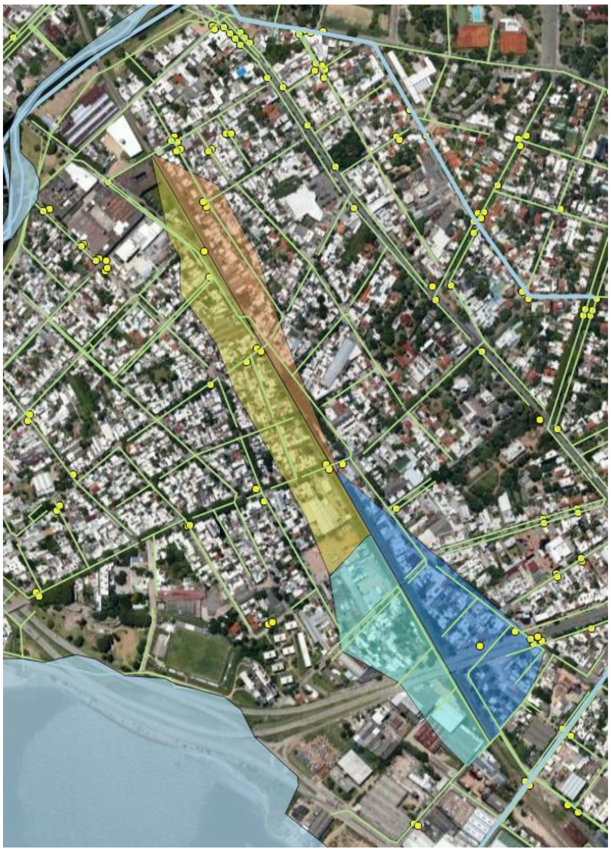

Figure 5-8Montevideo urban drainage catchments, inlets and conduits

In Table 5-3 sections for surface interceptors for Montevideo trench reach are calculated with a rectangular section with bottom width of 1.5 m.

Table 5-3 Montevideo surface interceptors channels 1.5 m width

Catchment	C	i (mm/h)	A (ha)	Q (m3/s)	L (m)	S (m/m)	B (m)	yn (m)	H (m)	V (m/s)
MVD-SW	0.88	217.79	5.1	2.7	462.6	0.011	1.50	0.55	0.69	3.26
MVD-SE	0.88	217.79	5.8	3.1	591.2	0.009	1.50	0.66	0.82	3.14
MVD-NE	0.88	217.79	3.5	1.9	711.1	0.017	1.50	0.37	0.46	3.43
MVD-NW	0.88	217.79	6.5	3.4	851.9	0.014	1.50	0.60	0.75	3.79

In Table 5-4 sections for surface interceptors for Montevideo trench reach are calculated with a rectangular section with optimum bottom width.

Table 5-4 Montevideo surface interceptors channels variable width

Catchment	C	i (mm/h)	A (ha)	Q (m^3/s)	L (m)	S (m/m)	B (m)	H (m)	yn (m)	V (m/s)
MVD-SW	0.88	217.79	5.1	2.7	462.6	0.011	1.3	0.79	0.63	3.28
MVD-SE	0.88	217.79	5.8	3.1	591.2	0.009	1.4	0.88	0.70	3.15
MVD-NE	0.88	217.79	3.5	1.9	711.1	0.017	1.0	0.67	0.54	3.53
MVD-NW	0.88	217.79	6.5	3.4	851.9	0.014	1.3	0.86	0.69	3.80

5.2.1.1. South of 3+580

This area drains towards Quitacalzones stream, hereafter dimensions of the required channels for the West and East side of railway are presented. Both of them should be connected to 12 de diciembre CSOs channel.

a) West

Maximum required dimensions for this reach, is a rectangular channel 1.30 m width and 0.80 m height.

b) East

Maximum required dimensions for this reach, is a rectangular channel 1.40 m width and 0.90 m height.

5.2.1.2. North of 3+580

This area drains towards Miguelete stream, hereafter dimensions of the required channels for the West and East side of railway are presented. Both of them should discharge towards Miguelete stream. As East catchment is smaller, pump station of sag point 4+000 should be connected to this side.

a) West

Maximum required dimensions for this reach, is a rectangular channel 1.30 m width and 0.90 m height.

b) East

Maximum required dimensions for this reach, is a rectangular channel 1.20 m width and 0.80 m height, receiving 4+000 sag point pump station.

5.2.2. Trench 2 in Las Piedras

In Las Piedras situation is very different, there are no combined sewers, and railway alignment is not on highest part of basins.

This case could be split in two as Las Piedras Station seems to be the highest point of railway elevation profile. Trench South of Las Piedras Station is in an area that drains towards Las Piedras stream, and North part drains towards Colorado stream.

Trench 2 is between chainages 18+627 and 21+200, approximately between South and North end of Las Piedras city as can be seen in Figure 5-9.

From the hydrological point of view the reach is between Colorado (North) and Las Piedras (South) Streams as shown in Figure 5-10.

In Figure 5-11 and Figure 5-12 the trench reach is presented over DTM and 2 m equidistant elevation contours in order to assess topography at the place. It can be seen there is a high terrain point between the two streams obviously.

With the aid of DTM, contour levels, inlets and conduits information, and Google Street view detailed sightseeing of the area subcatchments which can contribute surface runoff towards the trench were identified, delineated and presented in Figure 5-13.

Existing inlets, pipes and channels are presented in Figure 5-14, .

Figure 5-9 Location of trench reach in Las Piedras

Figure 5-10 Trench reach in Las Piedras and nearest streams

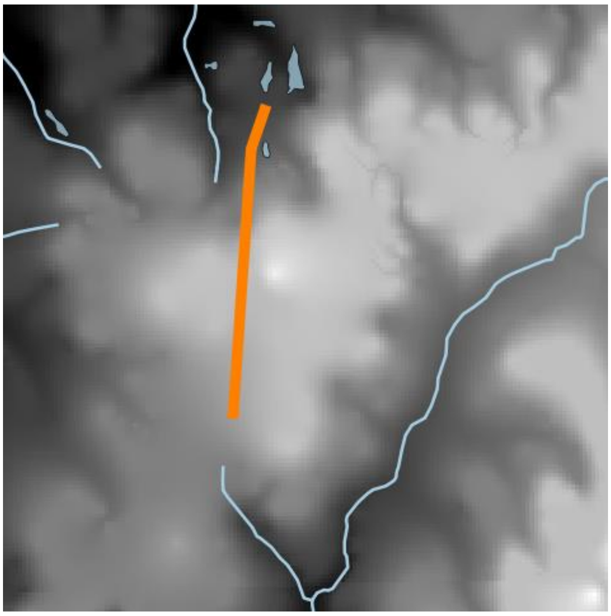

Figure 5-11 Trench reach in Las Piedras, streams and DTM

Figure 5-12 Trench reach in Las Piedras, streams and level contours

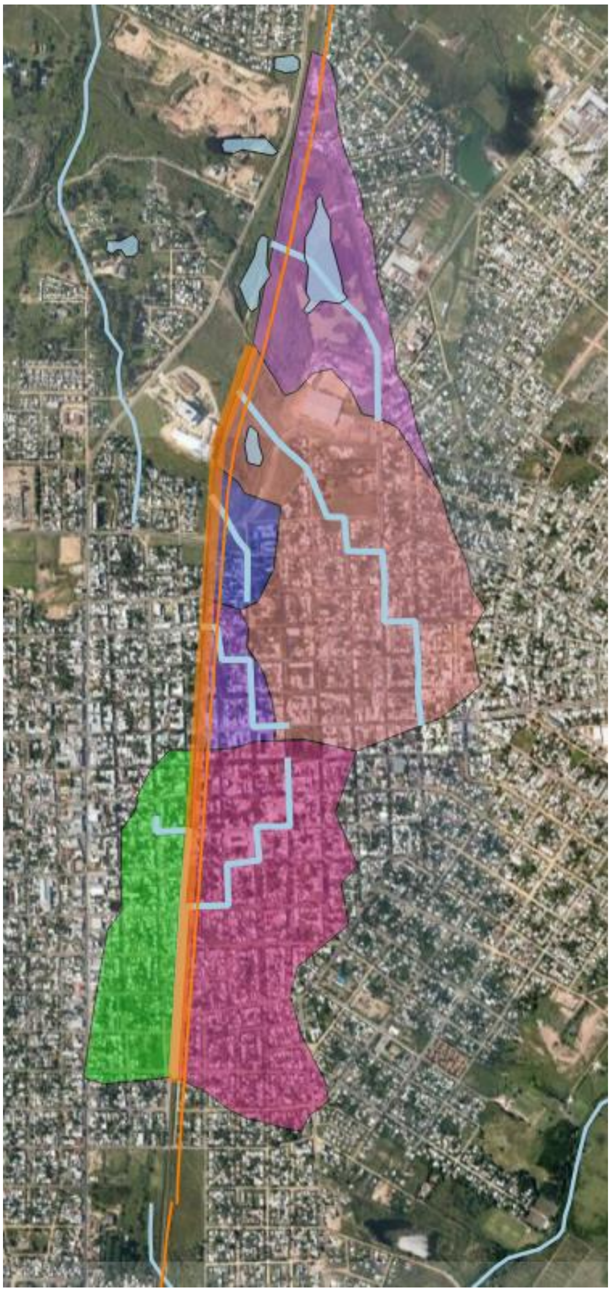

Figure 5-13 Las Piedras trench surface runoff catchments

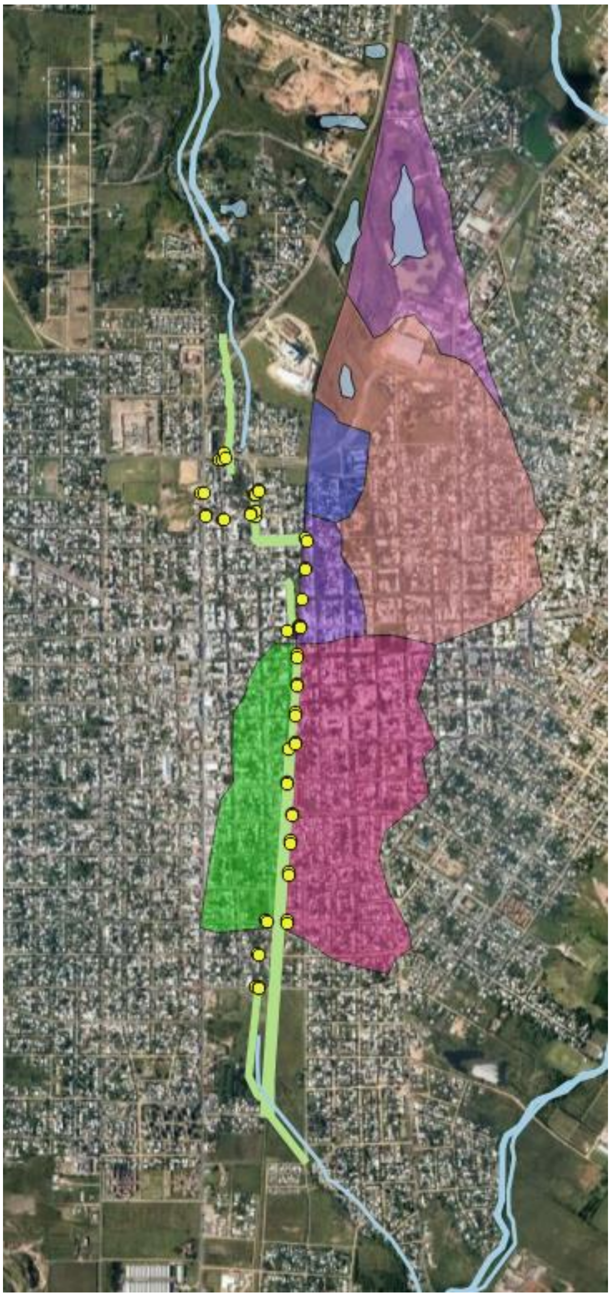

Figure 5-14 Las Piedras urban drainage catchments, inlets and conduits

In Table 5-5 the optimum cross sections for Las Piedras trench surface interceptors are presented.

Table 5-5 Las Piedras surface interceptors channels optimum width

Catchment	A (ha)	Cpond	L (m)	i (mm/h)	Q (m3/s)	S (m/m)	B (m)	yn (m)	H (m)	V (m/s)
LP-SW	21.8	0.78	874	158.50	7.5	0.008	2.00	1.00	1.25	3.76
LP-SE	48.7	0.78	1276	151.13	16.0	0.008	2.60	1.36	1.70	4.54
LP-NE-1	8.0	0.78	531	160.60	2.8	0.007	2.80	0.72	0.90	2.79
LP-NE-2	7.1	0.64	339	170.30	2.1	0.007	2.10	0.62	0.78	2.60
LP-NE-1+2	15.1	0.71	531	146.52	4.4	0.007	1.50	1.43	1.79	3.72
LP-NE-1+2+pump sag 20+000					5.2	0.007	1.80	0.89	1.11	3.26
LP-SW+pump sag 19+050					8.2	0.008	2.00	1.07	1.34	3.84

5.2.2.1. South of Las Piedras Station

This area drains towards Las Piedras stream, and in this case railway alignment almost coincides with the lowest points of the catchment or where the original stream was, that is why there are two large channels at each side of railway. Hereafter dimensions of the required channels for the West and East side of railway are presented.

c) West

West side has smaller catchment than East side, sag point at 19+050 should be connected to this side.

Maximum required dimensions for this rectangular channel should be 2.0 m width and 1.4 m height, receiving 19+050 sag point pump station.

d) East

Maximum required dimensions for this channel would be 2.6 m width and 1.70 m height, without receiving 19+050 sag point pump station.

5.2.2.2. North of Las Piedras Station

This area drains towards Colorado stream, in this case railway does not coincide with lowest points but it go across Colorado stream catchment which drains from South East to North West. Therefore there is more water expected from the East side than West side.

e) West

There is not much water expected from this side, unless connecting pump station at sag point 20+000, but does not make much sense to build another channel on that side just for the pumping station.

f) East

This ditch will intercept runoff which nowadays is capture by inlets and drained by pipes under railway. There are two catchments which might be all conducted towards stream at 20+680.

Maximum required dimensions for this channel should be 1.80 m width and 1.20 m height, receiving 20+000 sag point pump station.

6. Conclusions

For longitudinal drainage of rain falling directly into trench, 0.60 m width and 0.45 m height concrete rectangular channels are recommended. In case 20+700 is deepen, that channel would need 0.52 m height.

In order to drain sag points of trenches, most probably in the three cases, pump stations will be required, it is recommended that they are connected to the surface trench channel in order to provide a robust solution and do not depend on third parties operation and maintenance. Pump stations will have approximately following operation points:

- Sag at 4+000
  - $Q = 1.1\ m^3/s$
  - H > 6.83 m
  - P > 147 kw
- Sag at 19+050
  - $Q = 0.7\ m^3/s$
  - H > 7.54 m
  - P > 103 kw
- Sag at 20+000
  - $Q = 0.8\ m^3/s$
  - H > 8.08 m
  - P > 127 kw

Surface interceptors channels will have approximately following characteristics:

- Trench 1: Montevideo
  - South of 3+580
    - West
      - Rectangular: 1.3 m width x 0.8 m height
    - East
      - Rectangular: 1.4 m width x 0.9 m height
  - North of 3+580
    - West
      - Rectangular: 1.3 m width x 0.9 m height
    - East
      - Rectangular: 1.2 m width x 0.8 m height
- Trench 2: Las Piedras
  - South of 19+600 (Las Piedras St.)
    - West

        - Rectangular: 2.0 m width x 1.4 m height
    - East
        - Rectangular: 2.6 m width x 1.7 m height
- North of 19+600 (Las Piedras St.)
    - West
        - Rectangular: 0.6 m width x 0.45 m height
    - East
        - Rectangular: 1.8 m width x 1.2 m height

7. Annex