NUMERICAL SIMULATION TO STUDY THE WASTEWATER DISPOSAL PROJECT IN THE COASTAL ZONE OF BUENOS AIRES

A.N.Menéndez[1,2], N.Badano[2], M.Re[1,2], P.García[1,2], E.Lecertúa[1,2], F.Lopolito[1,2], A.Sarubbi[1,2]

[1]National Institute for Water (INA), Argentina; e mail: angel.menendez@speedy.com.ar
[2]National Technical University (UTN), Argentina

Abstract

A numerical model was built in order to analyze the performance of project alternatives, to update the central sewage system of the Metropolitan Area of Buenos Aires, regarding water quality of the coastal zone. Water use criteria were developed, by defining maximum concentration values for a set of representative water quality parameters. Presently, a strip with a variable width of a few kilometers, adjacent to the coastline, is not apt for any use. The model shows that: (i) a long extension of the coastal zone will be recovered for Secondary Contact Recreation; (ii) a significant reduction in width of the zone limited for Drinking Water by Conventional Treatment will be achieved; (iii) no further recovery for other uses of the coastal strip will be possible if pollution management plans are not implemented at least for the other two major urban watersheds contributing to pollution; (iv) relatively large limited use zones will be developed around the proposed outfall outlets; (v) secondary treatment of the outfall effluent would be superfluous.

Introduction

The water quality in the coastal zone of Buenos Aires – adjacent to a very wide estuary (about 50 km) with maritime hydrodynamic conditions, relatively small depths, and freshwater, known as 'Río de la Plata' – is very low due to a variety of discharges originated in the metropolitan region (Figure 1). Obsolescence of the central sewage system, which output to the estuary is through an old outfall with the outlet at 2.5 km from the coast, has led to uncontrolled discharges from both domestic and industrial sources, through the pluvial system.

A huge project (of the order of 2.5 billion American dollars) to update the central sewage system has been fostered by the Argentine Government through the Water Basin Authority (ACuMaR). The project includes (Figure 2): (i) dry-weather interception of pluvial discharges along a major part of the coastline, and along the banks of the main urban tributary (the Matanza-Riachuelo River); (ii) generation of transport capacity inland for the collected discharges; (iii) extention of the existing sewage net, eliminating septic systems; (iv) disposal of wastewater, after preliminary treatment, sufficiently far from the coast through two long outfalls (of the order of 10 km), so as to achieve high dilution conditions, and to significantly reduce the major source of coastal pollution.

A numerical model was built in order to analyze the performance of project alternatives regarding water quality goals for the coastal zone. Antecedents on the use of a modeling approach for this problem go back to the 80's (Carreras and Menéndez 1990). However, an integral approach, including all pollutant sources, and applying definite water quality criteria, was missing.

In the present paper, after a brief description of the model implementation, the application of the model to quantify the improvement in water quality associated to different project alternatives, based on water use criteria, is described.

Figure 1. Coastal zone of Buenos Aires

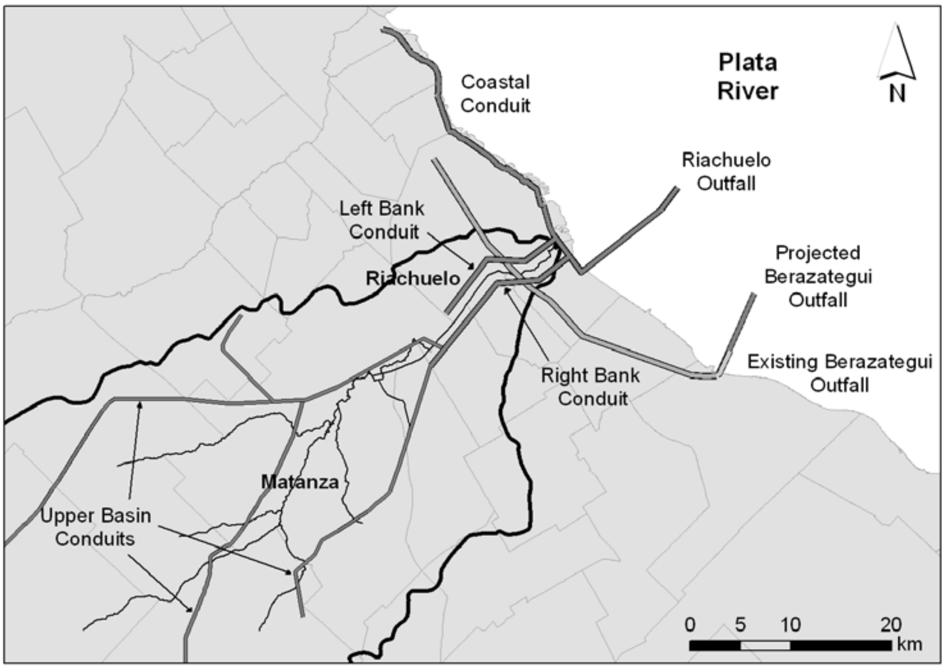


Figure 2. Scheme of wastewater disposal project

Model implementation

The model domain extends over an area of about 12,000 km^2, covering the entire inner Plata River. A 2D (vertically-integrated) hydrodynamic model, based on software MIKE 21 FM (Flexible Mesh) from DHI, with an eulerian approach, was implemented. The mesh density was increased in the coastal zone adjacent to Buenos Aires, i.e., in the problem zone.

Taking into account that in this area the maximum water depths are around 10 meters, and that the tidal wavelength is about 300 km (Menéndez 2001), the suitability of a 2D approach for the far-field problem follows. Technical details on 2D water quality models have been widely published (e.g., Martin et al. 1999).

The hydrodynamic model is driven by the tidal wave at the ocean boundary, the fluvial discharges from the main tributaries (Paraná and Uruguay Rivers, with total mean discharge around 22,000 m^3/s) at the estuary head, and the winds acting over the whole surface (Figure 3). It was calibrated based on velocity measurements (Figure 4).

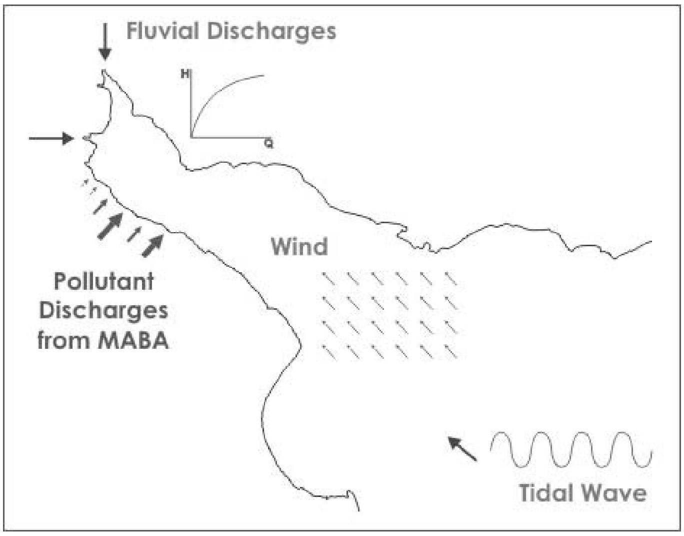
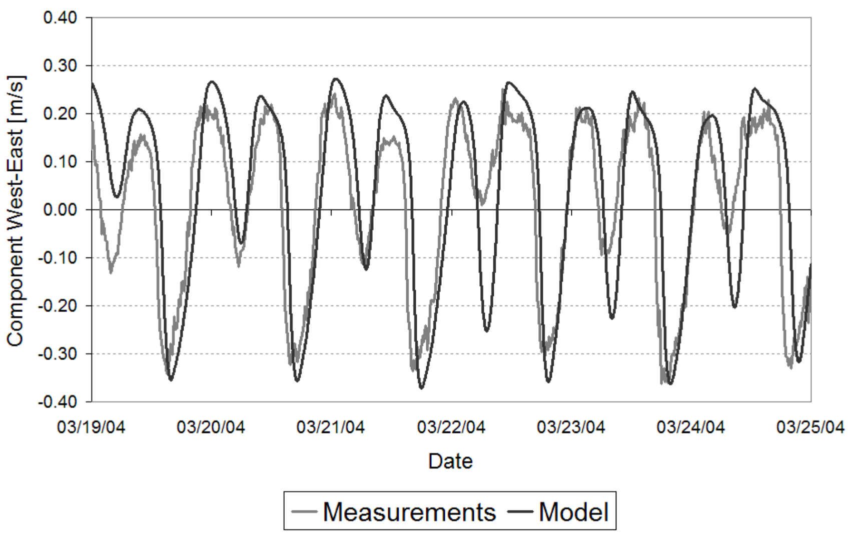
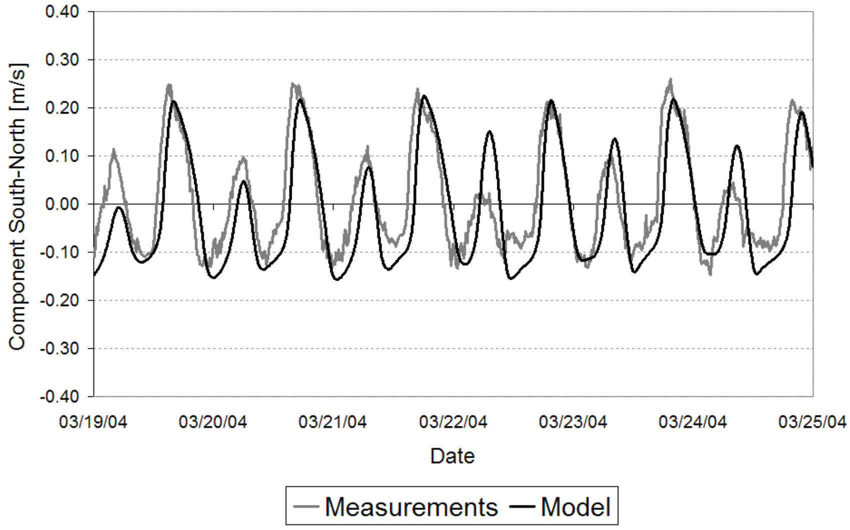


Figure 3. Driving forces



a) Component W-E



b) Component S-N

Figure 4. Comparison between measured and calculated velocities.

Data on pollutant discharges from natural and artificial outlets from the Metropolitan Area of Buenos Aires (MABA) was used to drive the pollutant transport model, based on software ECOLAB from DHI (Figure 3). The calibration of the transport model was undertaken based on measurements performed along the coastline (for approximately 80 km) and across the coastal zone, up to 80 km offshore. As an illustration, Figure 5 shows the distribution of time-mean concentrations of fecal coliform.

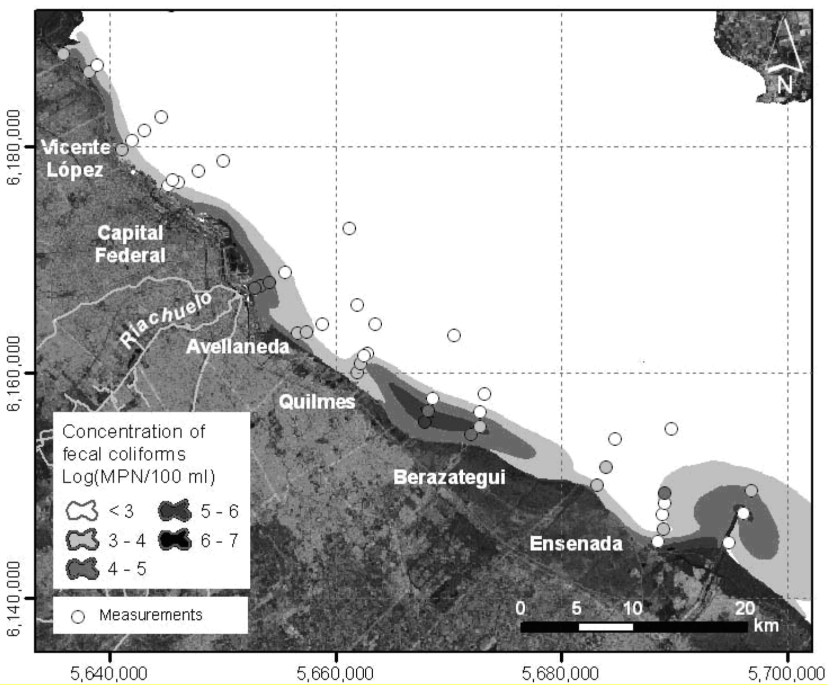


Figure 5. Comparison between measured and calculated mean concentrations for fecal coliform.

Numerical experiments were undertaken with a langrangian method, based on PT (Particle Tracking) from DHI, in order to establish the effects of numerical diffusion on the solution. As expected, the lagrangian model provided slightly narrower and longer plumes, but they did not lead to drastic deviations from the conclusions obtained with the eulerian model. Hence, the latter was used due to its much higher computational efficiency.

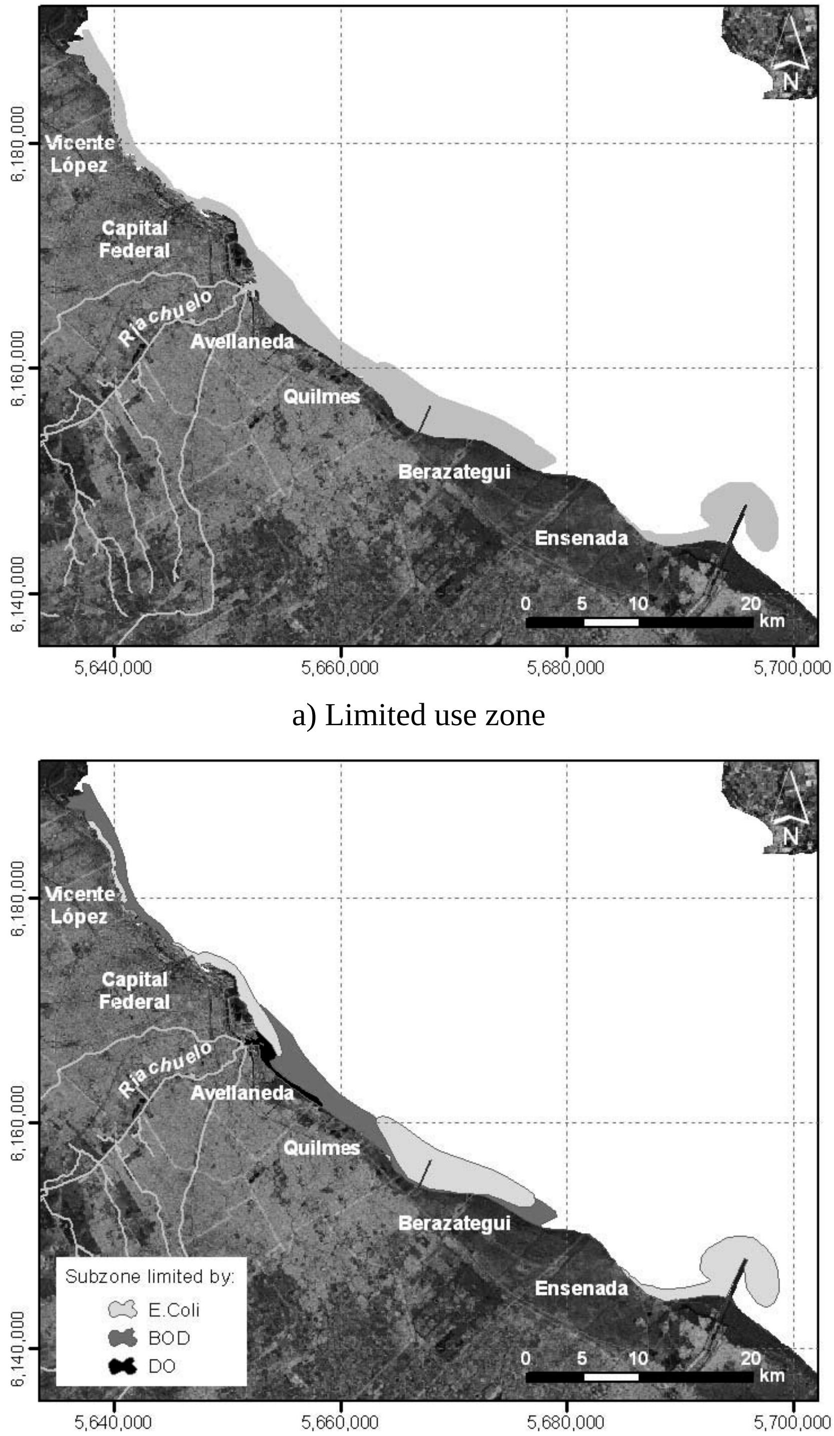
Water quality criteria

To analyze the performance of the project alternatives, water use criteria were developed, by defining maximum concentration values for a set of nine representative water quality parameters, not to be exceeded for a high percentage of time (90%). Six different uses were identified: (I) Drinking Water by Conventional Treatment; (II) Primary Contact Recreation; (III) Secondary Contact Recreation; (IV) Passive Recreation; (V) Preservation of Aquatic Life under Long Exposure; (VI) Preservation of Aquatic Life under Short Exposure. The basic water quality parameters used for the study were Dissolved Oxigen (DO), Biochemical Oxygen Demand (BOD), Ammonia, Nitrate, Escherichia Coli (E.Coli), Phenolic Substances, Detergents, Chromium (Cr), and Lead (Pb).

The adoption of water quality criteria (selection of parameters, and establishment of limiting values and percentage of fulfillment) is interpreted as a way of defining the level of risk; the wider the range of parameters, and the more restrictive the limiting values, the lower the risk that the admitted use could lead to some of the effects that are to be prevented. The decision on the level of risk to be adopted, which determines the design objective for a particular project, is conditioned by economic considerations. The final set of parameters and associated values are being defined by a Technical Committee within ACuMaR.

Present situation

Presently, a strip with a variable width of a few kilometers, adjacent to the coastline, is not apt for any use. As an illustration, Figure 6a shows the limited use zone for Use III. Figure 6b additionally presents a discrimination of the subzones limited by each of the representative parameters. It is observed that E.Coli and BOD are the main limiting parameters.



a) Limited use zone

b) Discrimination by parameter

Figure 6. Zone for Secondary Contact Recreation; present situation.

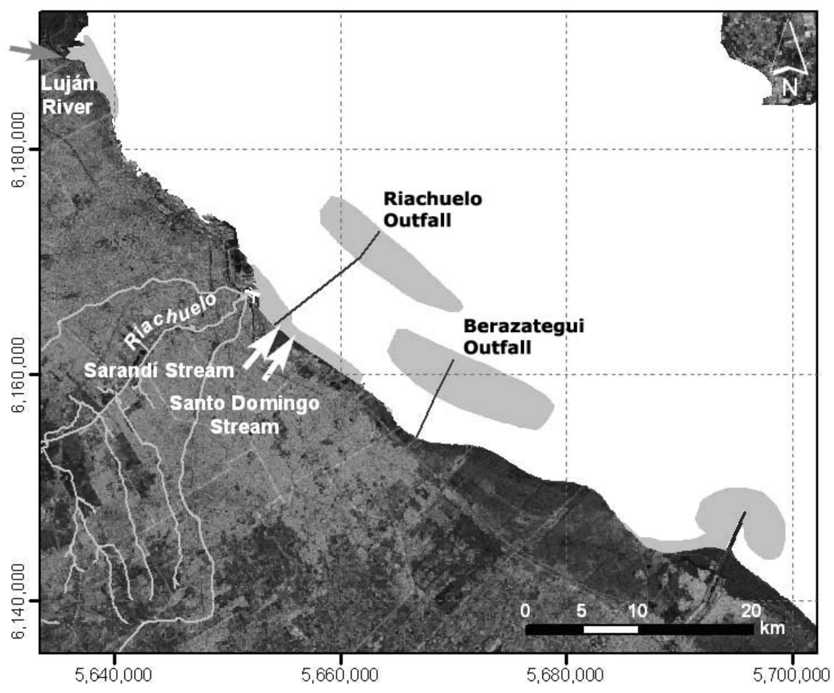
Project alternatives

The model was applied to study some alternatives of discharge through outfalls: the two long outfalls carrying different partitions of the total discharge (60 m^3/s), a long outfall combined with the present short one, and a single long outfall at the cross section of the present one. As an illustration, Figure 7 shows the limited use zone for Use III in the case of two long outfalls, with 'Riachuelo' outfall carrying 47% of the total discharge. It is observed that a long extension (about 40 km) of the coastal zone would be recovered for this use. As a counterpart, relatively large limited use zones will be developed around the outfall outlets (this is the environmental 'cost').

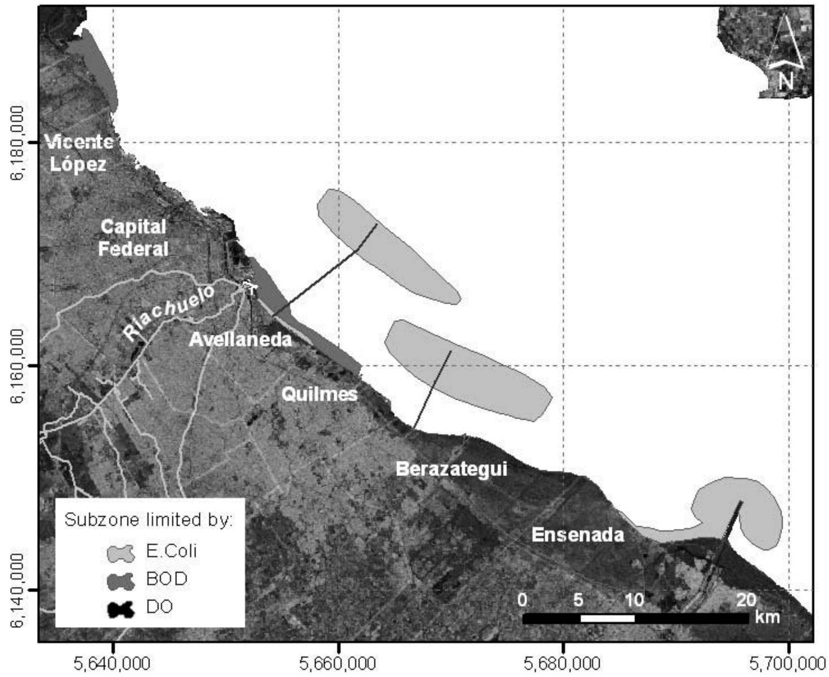
The model results also indicate that this alternative will allow a significant width reduction of the limited zone for Drinking Water by Conventional Treatment, reducing the risk level for the present two water intakes, located around 4 km from the coast. Additionally, it turns out that no further recovery for other uses of the coastal strip will be possible if pollution management plans are not implemented at least for the other two major urban watersheds contributing to pollution: Reconquista River, discharging to the Luján River, and Sarandí/Santo Domingo streams (Figure 7).

The alternative with one long outfall and the present short outfall was discarded, because the latter one imposes limitations on uses along the adjacent coastal zone. On the other hand, the single outfall alternative was also discarded, due to loss of flexibility of the in-land transport system, though its overall impact on the water body was lower in extension than the two-outfall project. Hence, the alternative with the two long outfalls was the one selected for construction.

Being E.Coli the parameter that determines the boundary of the limited use zones around the outfalls (Figure 7), and taking into account that a disinfection treatment is not feasible for economic and environmental considerations, it was concluded that secondary treatment of the outfall effluent would be superfluous.



a) Limited use zone



b) Discrimination by parameter

Figure 7. Zone for Recreation Without Direct Contact; project scenario.

Conclusions

The combined use of numerical models and water quality criteria, to define limited use zones, constitutes the appropriate methodology to assess the performance of wastewater disposal systems, and evaluate alternatives, including both selection of discharge points and level of wastewater treatment.

In particular, its application to the project developed for the Metropolitan Area of Buenos Aires has led to establish its expected performance, regarding recovery of the coastal zone, at the same time indicating the environmental ‘cost’, in terms of generation of new limited use zones.

References

Carreras, P.E., Menéndez, A.N. (1990). “Mathematical simulation of pollutant dispersion”, *Journal of Ecological Modelling*, 52, 29-40.

Martin, J.L., McCutcheon, S.C., Schottman, R.W. (1999). “Hydrodynamics and Transport for Water Quality Modeling”, CRC Press.

Menéndez, A.N. (2001). “Description and modeling of the hydrosedimentologic mechanisms in the Rio de la Plata River”, *Proceedings, VII International Seminar on Recent Advances in Fluid Mechanics, Physics of Fluids and Associated Complex Systems*, Buenos Aires, Argentina.

Acknowledgements

This work was made under contract with the “Secretaría de Ambiente y Desarrollo Sustentable” (Secretary for the Environment and Sustainable Development), Federal Government, Argentina. Fruitful discussions with Jorge Boll, Head of the Water Body Section, and his team are acknowledged.