JOURNAL OF
ENVIRONMENTAL HYDROLOGY

The Electronic Journal of the International Association for Environmental Hydrology
On the World Wide Web at http://www.hydroweb.com

VOLUME 7 1999

AN ENVIRONMENTAL IMPACT ASSESSMENT MATRIX MODEL FOR EMBANKMENTS IN FLATLAND LANDSCAPES

Nora Pouey
Margarita Portapila

CURIHAM (Centro Universitario de Investigaciones Hidroambientales)
Facultad de Ciencias Exactas, Ingeniéria y Agrimensura
Universidad Nacional de Rosario
Rosario, Argentina

A methodology is presented for assessing the environmental impacts produced by building embankments in regions of scarce surface relief. It is shown that the most relevant alterations affect surface runoff, which is the principal feature revealing the particular geomorphological aspect of flatlands, and the physical-chemical characteristics of the water. The methodology, which includes a matrix model of impact assessment, has been applied to flood protection dams built along the Ludueña Creek, Santa Fe Province, Argentina.

INTRODUCTION

The objective of this paper is to put forward the environmental problems created by building embankments in flatland regions, which are characterized by large areas of uniform elevation and very scarce relief. A methodological tool is provided based on a matrix model of environmental impacts.

Due to the virtual lack of surface slopes in flatland regions, any man-made construction that may alter surface runoff patterns has to be carefully thought out. Indeed, any embankment (railroads, highways, hydraulic routings) creates a hydraulic barrier affecting large areas of the natural drainage system.

Such a situation is particularly important in the vast flatland regions of Argentina because of the recurrence of major flooding events affecting large rural (productive) and urban areas, such as those located at the northern and central portions of Santa Fe Province, including the city of Rosario which is the second largest city in Argentina.

Although the major impacts are on surface runoff, other factors are also affected (physical, economical, social, and cultural components) which, in one way or another, are related to hydrological features.

Depending on the location of the embankment with respect to surface runoff, two types of construction can be distinguished: (a) dam-like, where the embankment is built perpendicular to the principal surface runoff direction, or (b) flood-protection, where the embankment is built parallel to the surface runoff direction.

Dam-like structures may have the following effects:

a) increasing the water height upgradient, and decreasing it downgradient,

b) increasing the extent of flooded areas upgradient, and decreasing them downgradient,

c) increasing the residence time of floods upgradient, and decreasing it downgradient,

d) overflow and/or destruction of roads or breaching of the dam due to rapidly rising water, and

e) destruction of bridges and hydraulic drainage systems downgradient due to increased surface water velocity caused by increased water elevation difference.

Flood-protection structures (assuming that no bridges are needed and that second-order watercourses are channeled to the main water course) may lead to:

a) increased water elevation (stage) for similar discharges. Breaching of a protection barrier usually has worse consequences than those without such protection.

b) the flooding effects downgradient becoming much more important than those without the protection, although locally those structures provide a certain degree of protection.

MATRIX MODEL FOR ASSESSING ENVIRONMENTAL IMPACTS

The methodology consists of setting up a matrix of cause-and-effect, as an expeditious way for visualizing and conceptualizing the various problems and their consequences. The rationale for choosing such a methodology is related to the lack of basic data and the largely unknown hydraulic behavior of large plains, which would allow the use of quantitative methods such as mathematical modeling.

The cause-and-effect matrix is flexible enough to incorporate particular problems voiced by the users, emphasizing factors or actions deemed important for a given project, or erasing files/columns which may not be relevant for certain purposes. Moreover, its cost is rather low, it can include interdisciplinary work, and it is easy to understand and to explain to direct users. It is also possible to quantify the problem and to compare alternative courses of action.

In order to start analyzing the problem, a major distinction of embankments is made according to their use:

a) Highway embankments.

b) Hydraulic embankments.

The assessment matrices are made up of files which represent factor or environmental indicators, and columns which contain information on the actions. Actions are grouped into actions during construction and actions during service of the embankment. They are as follows:

<u>Actions during embankment construction</u>

1) Location.

2) Source of extraction and transport of materials.

3) Landscape modifications.

4) Soil alterations.

5) Vegetal cover alterations.

6) Factors affecting the local fauna.

7) Settlement during construction .

<u>Actions during embankment service</u>

1) Maintenance work.

2) Security measures/structures.

3) Actions affecting biota.

4) Physical-chemical degradation.

5) Final alteration of the natural drainage.

6) Additional modifications of the landscape.

7) Likelihood of fires.

8) Soil alterations.

9) Other actions related to usage.

The factor or environmental indicators are divided up into two groups, geobiophysical and socioeconomic, which are themselves divided into subgroups.

Geobiophysical factors

They contain six subgroups, which describe the geomorphological and the biological situation, the climate characteristics, as well as the multiple interactions among the physical, geological, morphological, and human-related components of the system. They also describe qualitative, quantitative, and behavioral features of surface and groundwaters, and air quality.

1) Climate.

2) Soil.

3) Hydrology.

4) Water quality.

5) Air quality.

6) Biology.

Socioeconomic factors

They get divided into three subgroups, which describe the links among the economical, social, and cultural components.

1) Socioeconomic.

2) Health-related .

3) Cultural, recreational, and esthetic.

The interrelations or impacts are originally classified into:

Direct impacts.

Indirect impacts.

Further on, taking into account their effect and the time span of such effects, those impacts are classified into:

Irreversible negative impacts.

Permanent negative impacts.

Temporary negative impacts.

Positive permanent impacts.

Positive temporary impacts.

VARIABLE EVALUATION

This stage is of the utmost importance in any environmental impact study. All decisions should take into account different and sometimes contradictory viewpoints, and researchers are bound to balance various opinions.

In order to establish limits on the decision domain, a case study was selected, the flood protection dam on Ludueña Creek, Santa Fe Province. It was set up to compare each of the possible impacts with rules representing critical situations, and to eliminate those solutions that do not satisfy at least one of the rules. This is a non-aggregated multicriterion approach.

Depending on the aggregation criterion used, the evaluation techniques can be listed as follows:

a) Aggregated, monocriterion process: cost-benefit analysis.

b) Non-aggregated, multicriterion process: cost-efficiency analysis.

c) Aggregated, multicriterion process: with criteria weighting.

d) Non-aggregated, multicriteria process: without explicit weighting.

When it comes to evaluating the effects on the environment and working up the inventory, numerous scientific disciplines should be part of the tasks. For the Ludueña Creek case, the following criteria were taken into account to value the relative importance of a given impact:

- Impact relative importance, in terms of its amplitude and duration (a basin-scale model developed at CURIHAM in 1993 was used).
- Degree of match between the project and the development objectives of national and regional plans.
- Interests of community groups affected by the project (through polls and interviews).
- Use of special or unique environmental resources.
- Effects on health and security-related issues.
- Degree of interference with fundamental human activities in the area.
- Rules which govern the interplay of experts and members of the administrative public sector.

CONCLUSIONS

The surface drainage modification caused by Ludueña Creek flood protection (which cuts across the general direction of surface flow) has a positive impact on some factors of the environment. Indeed, some of the negative permanent impacts revealed by the general project become positive. Such are the quantitative changes in surface runoff, in the characteristics and uses of the flood plain, as well as in the overall features of floods and their concentration times (e.g., time to peak).

The smoothing effect produced by water being temporarily stored is also observed. This is caused by the fact that the water stored by the dam remains only for the time period needed to safely empty rainfall excess water (about 20 days maximum), so that its effects are negligible.

With respect to the maintenance and conservation actions, there are just a few minor interactions with environmental factors. They relate to the type of structure, which does not require much maintenance.

There are few animal and vegetation species in the dam area, so that the effects on biotic communities are not relevant .

As far as physical contamination, it can only be produced by materials carried by the Ludueña Creek because there is no vehicle traffic in the area.

Chemical contamination deserves a special mention. Inasmuch as the dam is set up in an area devoid of any sources of chemical contamination, the potential risk is negligible.

A different criterion was used to evaluate the impact caused by an eventual dam structural failure. Although the characteristics of the dam make failures virtually impossible, such a possibility has been taken into account as a technological risk (a physical model of the dam failure was developed as well as a mathematical model). Because of that, a number of negative irreversible impacts can be identified if such a structural failure occurs.

Finally, based on the research results and the experimental and mathematical models implemented, the conclusion is that no significant erosion related to water flow is expected to take place.

BIBLIOGRAPHY

B.A.H.C.; "Biospheric aspects of the hydrological cycle"; Report Nº 27; University Berlin, 1993.

Bendini, M., K. Andah and R. Harboe; "Water resources management: Modern decision techniques"; IAHR Proceedings 4; Ed. A.A.Balkema; Rotterdam; Netherlands, 1992.

Bertalanffy, L. V.; "Teoría general de sistemas"; Fondo de la Cultura Económica; México, 1990.

Bolea, M. T.; "Evaluación de impacto ambiental"; Ed. Mafre; Barcelona, 1984.

Bourgoignie, G. E.; "Perspectivas en ecología humana"; Colección Nuevo Urbanismo; Madrid, 1976.

Caspary, H.; "Forest decline and soil acidification as biospheric aspects of the hydrological cycle"; Proceedings of the Vienna Symposium, IAHS Pub. Nº 204, 1991.

Caubet, C. and B. Frank; "Manejo ambiental en bacia hidrográfica"; Fund. Agua Viva; Florianópolis,1993.

C.E.P.A.L.; "Desarrollo sustentado"; Ed. Naciones Unidas, 1991.

Christofoletti, A.; "Geomorfología"; Ed. Edgard Blücher Ltda.; Sao Paulo; Brasil, 1974.

Colombo, A. G.; "Environmental impact assessment"; Commission for the European Communities; Ed. Kluwer Academic Publishers, 1991.

James, A.; "An introduction to water quality modelling"; Ed. Wiley, 1984.

Margalef, R.; "Ecología"; Ed. Omega; Barcelona, 1986.

Mazza Alvares, J. A. and C. J. Orozco; "Las vías terrestres como obras hidráulicas". Revista Recursos Hidráulicos. N° 2, vol. 6, México, 1977.. FCNyF. UNC. 1995.

Pouey, N. and M. Portapila; Contribution to "Integrated River Basin Development". Ed. Wiley. Wallingford. England. l995.

Pouey, N. and M. Portapila; "Environmental Impact Evaluation Model for Dredging Activities." Fourteenth World Dredging Congress. Proceeding WODA Amsterdam. l995.

Pouey, N. E.; "Drenaje superficial. Alcantarillas". Departamento de Hidráulica e Ingeniería Sanitaria. FCEIA. UNR. 1986.

Pouey, N. E.; "Erosión hídrica en suelos cohesivos". Tesis Doctoral. FCEIA. UNR . 1997.

Pouey, N. E.; "La presa de retención de crecidas del Arroyo Ludueña". Reporte de Investigación. Departamento de Hidráulica e Ing. Sanitaria. FCEIA. UNR. 1987.

ADDRESS FOR CORRESPONDENCE
Nora Pouey
CURIHAM (Centro Universitario de Investigaciones Hidroambientales)
Facultad de Ciencias Exactas, Ingeniería y Agrimensura
Universidad Nacional de Rosario
Riobamba 245 bis
2000 Rosario
Argentina

E-mail: curiham@fceia.unr.edu.ar