Effect of time of confinement over groundwater contamination at a feedlot: its evaluation through electrical resistivity tomography.

Márquez Molina. John J.[1], Sainato Claudia M.[1], Losinno Beatriz N.[1]

[1]Catedra de Física. Facultad de Agronomía.
Universidad de Buenos Aires. Argentina

Abstract

The aim of this work is to study the effect of time of confinement of bovine animals at feedlot over groundwater contamination. Electrical resistivity tomography was performed to detect the anomalies and to find out the sites for drilling pits to study soil characteristics and wells to analyze phreatic aquifer. The results show higher degree of contamination at the corral where the phreatic aquifer was more superficial, even if the cattle activity had begun four months before.

Introduction

The cattle activity in pastures in Argentina is being progressively changed by an intensive system of feeding in corrals (feedlots) where animals are confined, with diets of high energetic concentration and high digestibility. This system generates large quantities of liquid and solid wastes (Pordomingo, 2001).

The electrical resistivity tomography gives the distribution of apparent conductivity with depth, which may give an image of salinization zone which allow a guided sampling of soil and groundwater. The apparent conductivity is related with water content, texture, salinity and hydraulic properties (Slater, 2006). These methods are not widely used for monitoring contamination by animal sources. There are some electromagnetic studies of nitrate contamination of groundwater at dairy farms; Darling (1992) and Drommerhausen et al. (1995) detected contamination at the zones of animal concentration, at the lagoons of effluents or septic wells. Losinno et al. (2008) found, by means of electrical tomography at dairies, that the lagoons or channel of effluents are a point source of contamination of soil and groundwater. The degree of contamination must be related with vulnerability of the site, which in the classic approaches is assumed to be calculated with the phreatic depth, the texture of the non saturated zone (NSZ) and the hydraulic conductivity. The soil effect of attenuation is not, in general, taken into account. The soil profile may attenuate a great part of the contaminants, and some studies were done trying to incorporate this factor in the estimation of vulnerability (Blarasin et al., 1995), (Sainato et al., 2006); (Heredia and Fernandez Cirelli, 2008). However, this will depend on the physico-chemical characteristics of soils and the type of land use or management of the production (Martínez et al., 2008). This work is part of a Project to investigate the dependence of vulnerability on soil properties and management practices using electrical methods. The objective of this work is to analyze contamination of soil and groundwater at a feedlot and its dependence on soil features and management practices, particularly time of confinement, using electrical tomography.

Method

Study zone

The feedlot is placed at the vicinity of Trenque Lauquen, at the W-NW of Buenos Aires Province, Argentina (Figure 1). It is located at the region of the Chaco Pampeana plain (with a regional slope from W to E of 25 cm. per km), where the “pampean sediments” are covered by eolic sands, related to the so called “invasive dune”. At the depressions, lacustrine and fluvial sediments are found partially covered by the “invasive dune” which is classified as the aquifer formation due to its areal extension (Frenguelli, 1950). From the hydrological point of view the study zone has practically no superficial watercourses and there is a predominance of vertical movement of water (precipitation, evaporation and infiltration) over the horizontal one.

From 1970, there has been an increase of the annual rate of average precipitations, being around 900 to 950 mm per year. At the northwest of Buenos Aires province, from 1970 to 2002 precipitations had an average increase greater than 150mm per year (Proyecto PNUD ARG, 2006). Therefore, there exists a proportional relation between the phreatic level variations and precipitation and excess of water. During humid periods, the elevation of phreatic levels may generate floods at the lower zones, and at drought periods the decrease of precipitation may produce great decrease of groundwater levels. Soils were characterized (Heredia, personal communication) as sandy loamy.

Electrical soundings

The geoelectrical exploration was carried out at two lots at the feedlot (Figure 1), each one with different times of animal permanence: Lot 1 is a corral where 297 bovine animals have been confined for four months previous to the survey; lot 2 does not have a permanent presence of animals but it has been working and breeding animals for seven years before the survey.

Electrical resistivity tomography was carried out along lines perpendicular to the topographic slope, following the patterns for environmental studies (IHOBE, 2003) (see Figure 1). Dipole-dipole configuration was used with an electrode separation of 2 m and maximum distance of 50 m (measurements were made up to n=6). Experimental

data were inverted to obtain 2D models of electrical resistivity using the code dcip2D (UBCGIF) developed with the approach of Oldenburg and Li (1994). The direction of lines is perpendicular to the direction of maximum variability of conductivity since at both lots, line 1 is at the dome: at lot 1 the feeding trough is now placed along this line and in the middle of the slope the drinking trough is placed. Lines are in the direction SW-NE and the topography decreases with the increasing number of line. The background soundings were carried out at an adjacent path (line 11 for lot 1, line 1 for lot 2) without the influence of animals and situated up gradient the corrals and the potential sources of contamination (feeding and drinking trough).
Two wells were drilled at lot 1 to analyze the phreatic aquifer (C1-1 and C1-2); another well with a mill is placed at the dome zone up gradient. C1, C2, C3 and CT represent four deep pits that were drilled, following the contrasts in resistivity obtained from the soundings, to characterize soils (Heredia, personal communication) and to analyze concentrations of contaminants. CT is the background pit. At lot 2, lines has the direction NW-SE. One well (CT2), just by the drinking through, was drilled to monitor the phreatic aquifer and wells CT1 (mill) and CT3 were already existing. An abandoned feeding trough is placed along line 2 and the drinking trough is placed perpendicular to the lines near well CT2 and pit C1T.
In all the cases, physico-chemical analysis was performed to soil and groundwater samples.

Results

Figure 2 and 3 show the models of electrical resistivity of the earth for all the lines at the two lots. Figure 4 shows the observed and predicted data for soundings were the pits are placed.

At lot 1, Line 11 (background) shows non saturated zone (NSZ) with a very high value of resistivity due to soil with high content of dry sands (over 250 ohm m). Phreatic level at this lot was measured at 2.94 m of depth approximately. Resistivity of NSZ decreases with topography, reaching at line 6, after the drinking trough, values below 70 ohm m. Below line 1 high values of resistivity may be due to the presence of a calcareous crust plate deliberately located below the feeding trough. Saturated zone (SZ) below 3 m depth has values of resistivity that decrease from the dome to the low part of the corral (from 20-70 ohm m to 2 ohm m). Electrical conductivity measured in groundwater was 2200 and 3500 µS/cm for C1-1 and C1-2, respectively.

At lot 2, line 1 is the background sounding with high values (300 ohm m) of resistivity of NSZ, composed by sands with a high degree of compactation. The SZ has around 40 ohm m of resistivity, taking into account that the phreatic level was found at around 7 m depth. The following lines show a decrease of resistivity towards the low zone, but this decrease is stronger at the NW side of the profiles in the direction of the drinking through.
The saturated zone does not show a great contrast of resistivity between the background site line 1 and the low zone (line 6) and the values are higher than the ones obtained at lot 1. Electrical conductivity measured in groundwater was 600, 900 and 1500 µS/cm for wells CT1, CT2 and CT3 respectively.

Comparatively, electrical conductivity from sounding results and from analysis of groundwater show greater values for lot 1 than for lot 2. Nitrate levels are similar at both lots (around 70 ppm), while sulphates are much higher at lot 1 than lot 2 (6.34 meq/l versus 0.54 meq/l). The same trend is present in Chlorides (8 versus 1 meq/l) and phosphorous (8 versus 0 ppm).
Although lot 2 has been confining animals for longer time than lot 1, the concentrations of contaminants in groundwater are greater at the second one, in agreement with geoelectrical results. The thick texture of soils, together with the not very deep phreatic level at lot 1, probably make contaminants reach groundwater at short times, even if the animal charge at this lot has not been so long in time. However, the phreatic aquifer at lot 2 seems to be less vulnerable, due to greater depth of groundwater, in spite of the fact that animals have been confined periodically for seven years. The higher mobility of nitrates may be the cause of similar concentrations in groundwater at both lots.

Conclusions

Electrical resistivity tomography has been sensitive to detect the anomalies of electrical conductivity associated with an increase of contaminants in groundwater. The preliminary results of this work show that the depth to the phreatic level is a decisive factor for vulnerability, even more influent than the time of confinement of the animals, hence the time period of the animal charge. Further studies will be carried out, to confirm these results and to compare them with the ones obtained at feedlots located at zones of finer soil texture.

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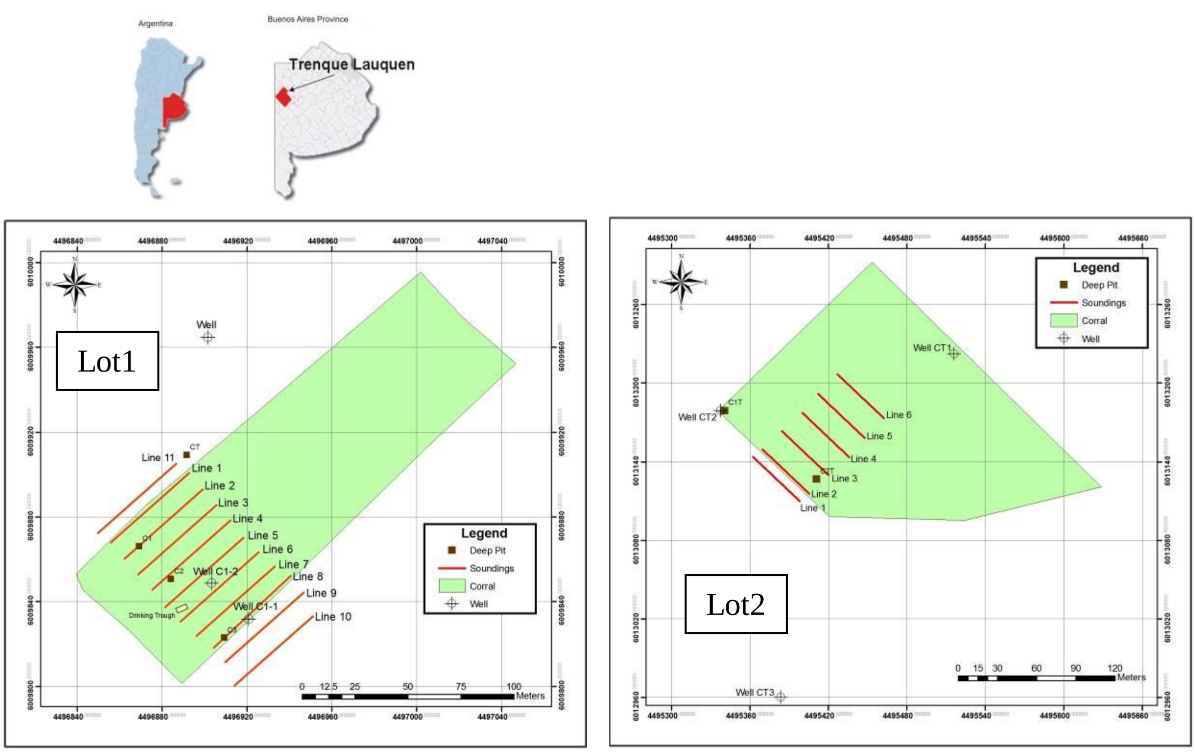

Figure 1. Study zone. Plots of the corrals (lot 1 and lot 2) with lines of electrical soundings, wells and deep pits

Effect of time of confinement

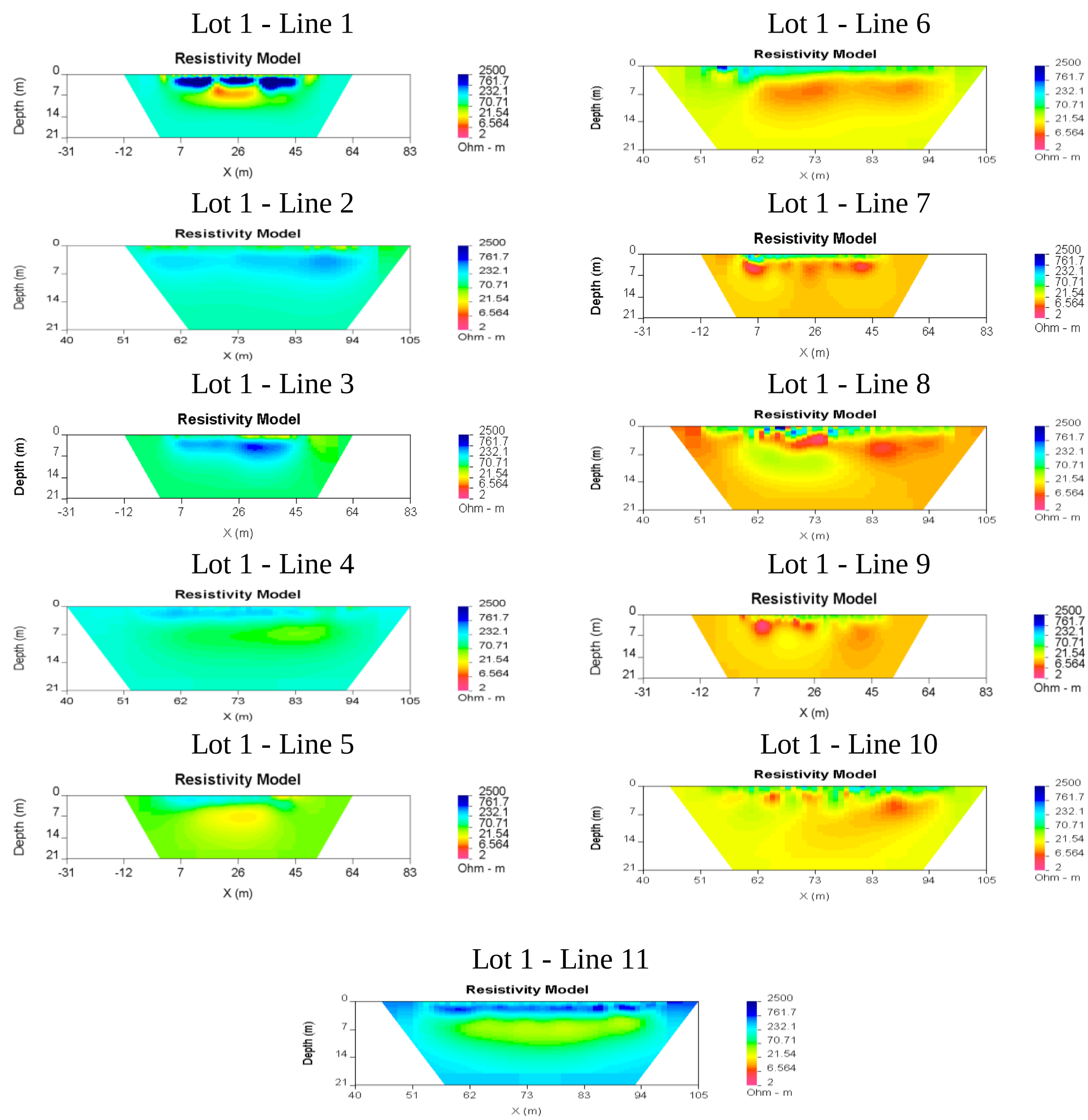

Figure 2. Electrical resistivity models for lot 1

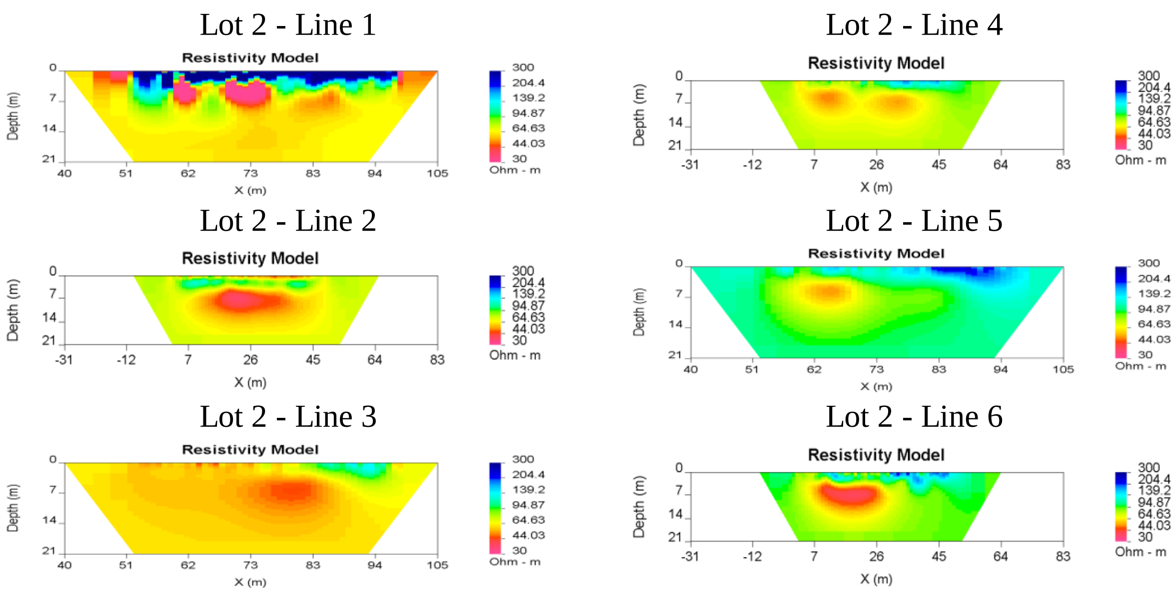

Figure 3. Electrical resistivity models for lot 2

Effect of time of confinement

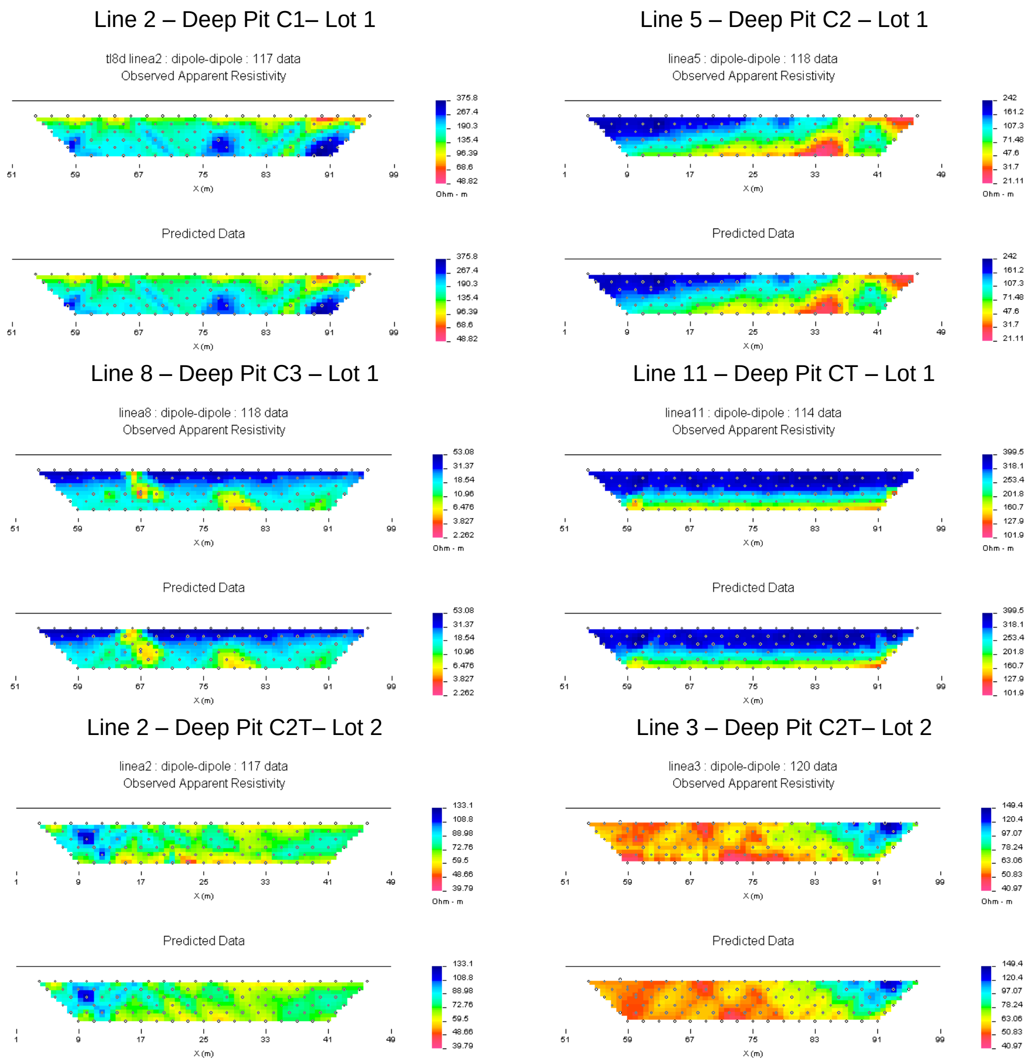

Figure 4. Observed and predicted data for lines were deep pits were drilled.