LOW COST REMOTE SENSING INVESTIGATIONS OF A WASTE DUMP NEAR ZAGREB

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ABSTRACT:

For the Jakusevec waste dump near Zagreb Landsat TM data (1984, 1990, 1992) as well as SPOT P (1994) have been analysed. Geological-structural terrain relations have been established by visual and digital analysis of these images. Also, old river backwaters and meanders, and areas of an increased soil moisture content were discarded. Based on multitemporal Landsat imagery of the surroundings of Jakusevec a change detection with 10 classes has been made. Panchromatic and infrared airphotos from 1968, 1977, 1980, 1981 and 1989 as well as airborne thermographic images from 1974 were also used.

Since in 1965 the filling of the waste disposal began, it was possible to observe its spatiodynamic and to register thermal anomalies in parts of the waste site. The increase in the waste volume during the period from 1968 to 1989 was calculated by photogrammic measurements on stereo-models from 1968, 1977, 1981 and 1989. For this period the calculated volume of waste is 3.129.053,00 $m^3$. Today's total waste mass amounts to 5.183.053,00 $m^3$.

At the beginning the waste was disposed into river backwaters and abandoned gravel pits and thus it came in direct contact with ground waters, that may affect ground water quality. Interpretation of airphotos between 1968 and 1989, also showed that there are no significant damages of forests in the surroundings of the site.

It can be concluded that in terms of speed, accuracy and economy remote sensing is probably the most reliable methodology for the investigation of existing waste disposits and for the determination of the most favourable sites for waste disposal.

## 1. INTRODUCTION

Human activities are accompanied by large amounts of waste, which, as a society develops, increases rapidly. Various solutions are being suggested, from classical burning, through pyrolitic processes and composting to complex recycling systems. However, at the current economic and technological development rates, longterm waste disposal on or in the soil is still the most acceptable solution for most countries. This inevitably causes harmful impacts on air, soil and water.

Old waste disposal sites represent a specific problem since they are usually in locations which have not been properly examined. Data about the amount and type of waste is mostly not available, in addition to a lack of information on its impact on the environment. It is then necessary that all these facts are investigated in hindsight, so that the negative impact of the waste dump on the environment can be estimated and a remediation can be carried out.

This paper examines the joint application of air- and spaceborne remote sensing methods in the investigation of old waste disposal sites, using the Jakusevec waste dump near Croatia's capital Zagreb as an example.

## 2. INVESTIGATION METHODOLOGY

The majority of the locations in Croatia where waste is discarded are not properly prepared, and waste was deposited in a totally unorganized way. That is why such places should rather be called waste dumps, in contrast to organized landfills.

Terrestrial investigation methods of existing waste dumps are very complex, time-consuming and expensive. That is one of the reasons for the use of new methods, i.a. remote sensing, which have been proved to be very useful in solving the above-mentioned problems and, in addition, when compared to traditional methods, much faster and cheaper. These methods do not exclude the application of classical terrestirial techniques, but rather complement them. Remote sensing allows us to collect data difficult or practically impossible to obtain by classical procedures (Philipson et al 1981, Lyon 1987, Herman et al 1994, Vincent 1994, Kühn & Hörig 1995).

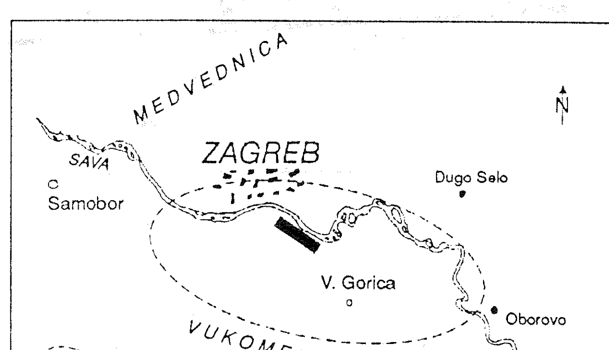


Figure 1: Landsat TM image of the Zagreb Area

By means satellite observations it is possible to detect geo-structural elements of the area where the waste is disposed. Of special importance is fault tectonics, which can have an effect on the relationship between the lithofacies in which the waste is deposited and the site selection. Larger faults are important because of possible seismological activities and potential ground deformations across such faults in the event of an earthquake. Furthermore, it is possible map „buried" river backwaters and meanders, which are usually very hard to detect on the ground, in addition to the determination of the ground moisture content. This information helps in the determination of the hydrogeological characteristics of the area.

Metric stereo airphotos are also a very significant source of information concerning the terrain on which the waste dump is located and the waste dump itself. Time series enable us to determine changes of the waste dump site, the vegetation surrounding of the dump site, and the volume of waste disposed, which is compared to terrestrial methods, faster and less expensive. On thermal infrared aerial images one can determine anomalies at the surface of the waste dump, which indicate higher temperatures in relation to the surrounding area.
By analyzing these images it is possible to determine the level of decomposition activity.

## 3. INVESTIGATION OF THE JAKUSEVEC WASTE DUMP

The Jakusevec waste dump is situated on the right bank of the Sava River, at the southeastern periphery of the city of Zagreb, some 6 km from the center. Newer parts of Zagreb are only about 1000 meters away from the site, and it is only a few hundred meters from the dump to the first houses of the village of Jakusevec (Fig. 1).

### 3.1. Analysis of structural geological characteristics

The Jakusevec waste dump is located in Quaternary clastic sediments of mostly alluvial lithofacies and heterogenic composition. The sediments are mainly small-grained sands and clays with strata of an average thickness of about 2-3 m (Mayer & Markovac, 1992). Due to the exploitation of construction gravel these sediments have been removed in some places. Under these layers there are gravels and small-grained sands, which alternate vertically and horizontally.
The thickness of the layers under the waste dump varies between 40 and 50 meters (Fig. 2). These gravel-sand sediments are the main aquifer in this area.

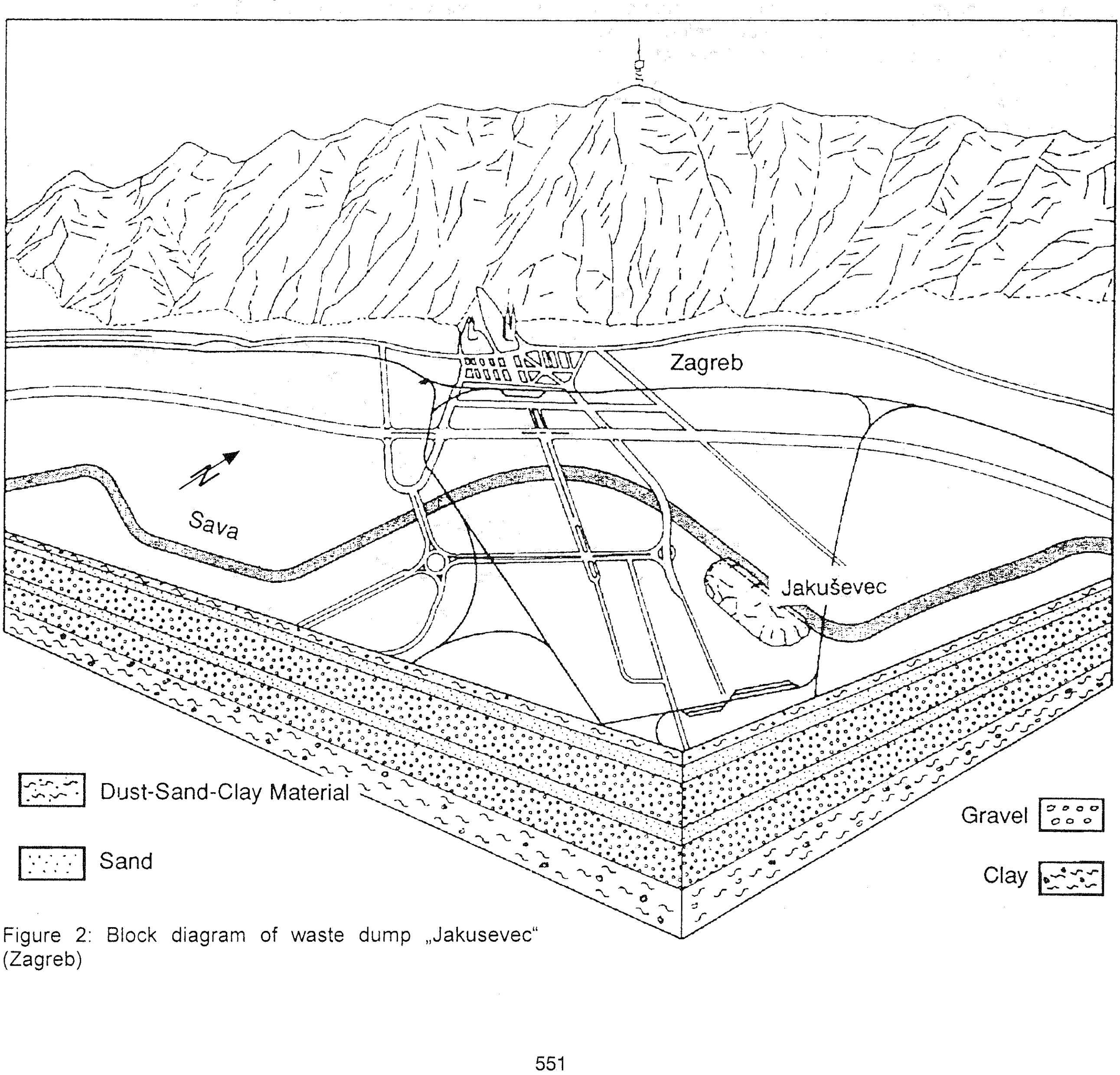


Figure 2: Block diagram of waste dump „Jakusevec" (Zagreb)

In the structural-tectonic sense, the terrain is a part of the Sava Depression, which is distinguished by its complex structure and composition. The basic characteristics of the structural relationship is block structures resulting from radial tectonics (Velic, 1983).

On the satellite images, faults of various intensities and spreading directions are observed. Amongst them the most noticeable ones are those which surround the Sava Depression (the Medvednica-Kalnik Fault, the northern Sava Depression Fault, and the fault that stretches along the Vukomericka Gorica - the Southern Depression Fault). Also important is the transcurrent fault which trends from Dugo Selo in southwestern direction. Inside the depression many small, less important faults were detected (Fig. 3) which determine the block structure. Among the lateral faults the most pronounced ones are those striking in the directions Zadvorsko-Maksimir, Lukavec-Drenje and Rugvica-Kuce. The most significant meridional spreading fault is the one that runs from Podsused over Rakitje to Rakov Potok.

The Jakusevec waste dump is situated inside the Zagreb epicenter area, i.e. in the immediate vicinity of the source of possible strong earthquakes which can result in deformations in the soil along the fault zone with a magnitude ranging from a few centimeters to several decimeters. In addition, the waste dump is located on an area in which the Sava used to flow before it was regulated. You find many small „buried" backwaters and meanders in its vicinity. They are in most cases sediment-filled and overgrown by vegetation and easily detectable in aerial and satellite images (Fig. 4).

Multitemporal Landsat TM images (1984, 1990, 1992) have been used for classifications of the wider area around the waste dump site with ten important terrain categories. Comparsons of images from different dates show changes that have occurred between the two data takes. Also, a merged Landsat TM and SPOT P image has been used to map old river channels and meanders, as well as the hydrographic net, which is manifested through the surface and near-surface moisture content.

### 3.2. Analysis of waste dump growth

Waste transport to the Jakusevec waste dump began in 1965. The earliest aerial photographs available stem from 1968 and have a scale of 1:18750. Based on these images it was tried to map the terrain relief before the waste depositing. It is a rather devastated terrain with numerous depressions resulting from gravel removal and also a few lakes in the old gravel pits. Small quantities of waste were only observed in two locations. The dimension of the one closer to the Sava dam were approximately 200 x 100 m², whereas the smaller one was only 80 x 40 m².

Airphotos from 1977 show a spreading of the waste dump into northwestern and southwestern direction along the Sava riverbank, the total length now being around 1400 m, the total width approximately 350 m.

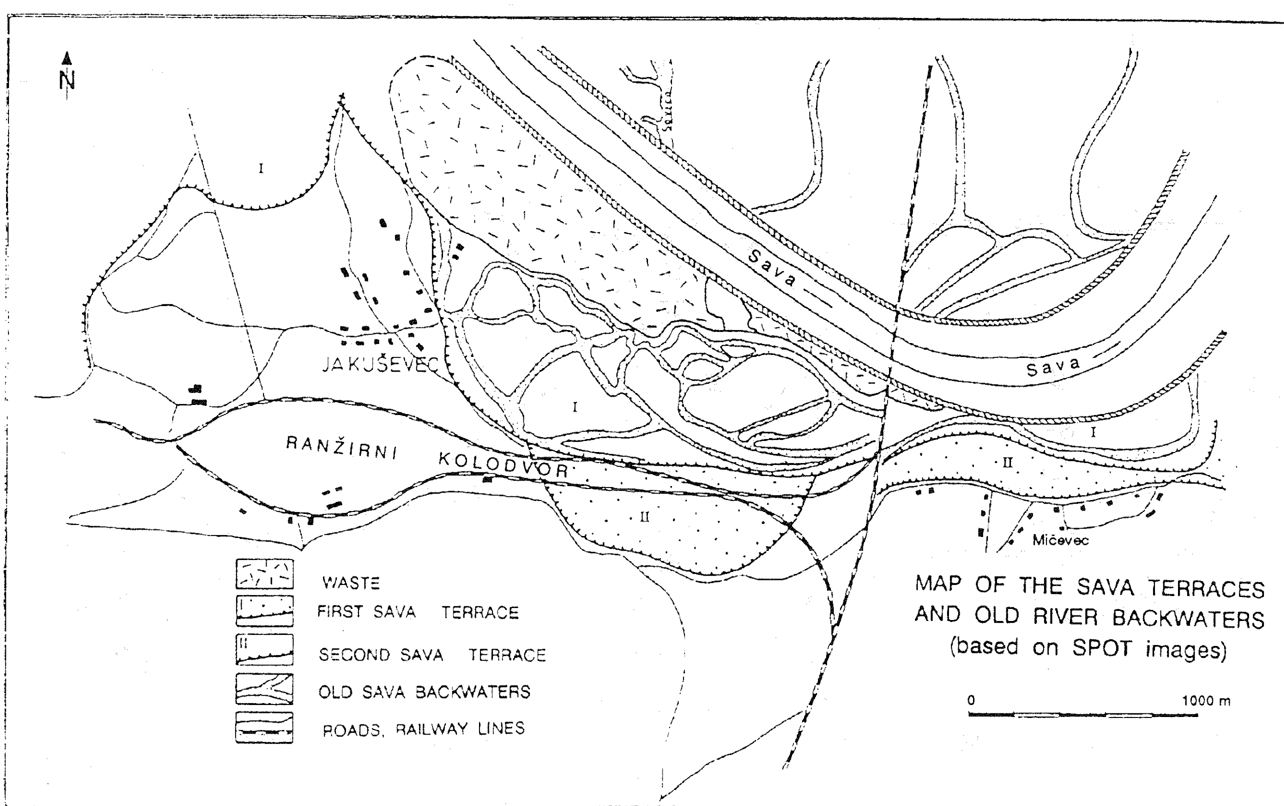


Figure 3: Hydrographic network and fluvial terraces near the Jakusevec waste dump, based on Landsat TM and mainly SPOT panchrom imagery

CIR airphotos from 1980 show drastic changes of the terrain surface. Almost all of the depressions (gravel pits) which constitute the base of todays waste dump and which were registered on the aerial photographs of 1968 were totally filled with waste. From the main entrance the thickness of the waste grows in southeastern direction up to a distance of about 700 m.

Towards the railway bridge (Fig. 1) there is a more recent waste dump, of 400 x 570 m². Near the road bridge another new waste site had developed. Its size is approximately 380 x 280 m². New active gravel pits were observed.

Aerial photographs from 1981 have also been analysed and showed a further spreading of the waste dump in southeastern direction. Waste has also been deposited along the Sava riverbank, all the way to the railway bridge. There was also spreading in a southeastern direction from the bridge.

The 1989 aerial photographs at a scale of 1: 4650 clearly show the borders of the waste dump, which were at that time already adjacent to the village of Jakusevec. In addition, a Sava backwater, which in 1980 was still outside the northeastern border of the dump, was now almost completely covered with waste. The southeastern portion of the waste dump was now connected with the northwestern portions and they formed a single big mass. Waste was mainly deposited in the central area. That year, the dimensions of the waste dump were around 1400 x 470 m².

Near and thermal infrared images of the waste dump have been analysed, too. There three portions of the waste dump can be identified: a southeastern, a central, and a northwestern portion. This is probably a result of different thickness and compositions of the waste and different decomposition rates. Aerial thermograms taken in 1974 by a DS-1250 multispectral Daedalus scanner show increased thermal anomalies in comparison to the surrounding area. Some parts of waste dump were very pronounced.

### 3.3. Waste quantities

The quantities of waste deposited on the Jakusevec waste dump between 1968 and 1989 has been determined by photogrammetric measurements on airphoto stereomodels using a Leica BC-3 analytical stereo plotter and Aviosoft software. The volumina of the waste have been calculated by means of digital elevation models (DEMs), taking the original landscape level at 104 m above sea level.

The data obtained by the measurements and calculations result in the following table:

| year | total volume (in m³) | waste addition (in m³) | total waste dumped (in m³) |
|---|---|---|---|
| 1968 | 4.764.031,00 | | |
| 1977 | 5.418.400,00 | 654,396,00 | |
| 1981 | 6.320.903,00 | 902.503,00 | |
| 1989 | 7.893.057,00 | 1.572.154,00 | 3.129.053,00 |

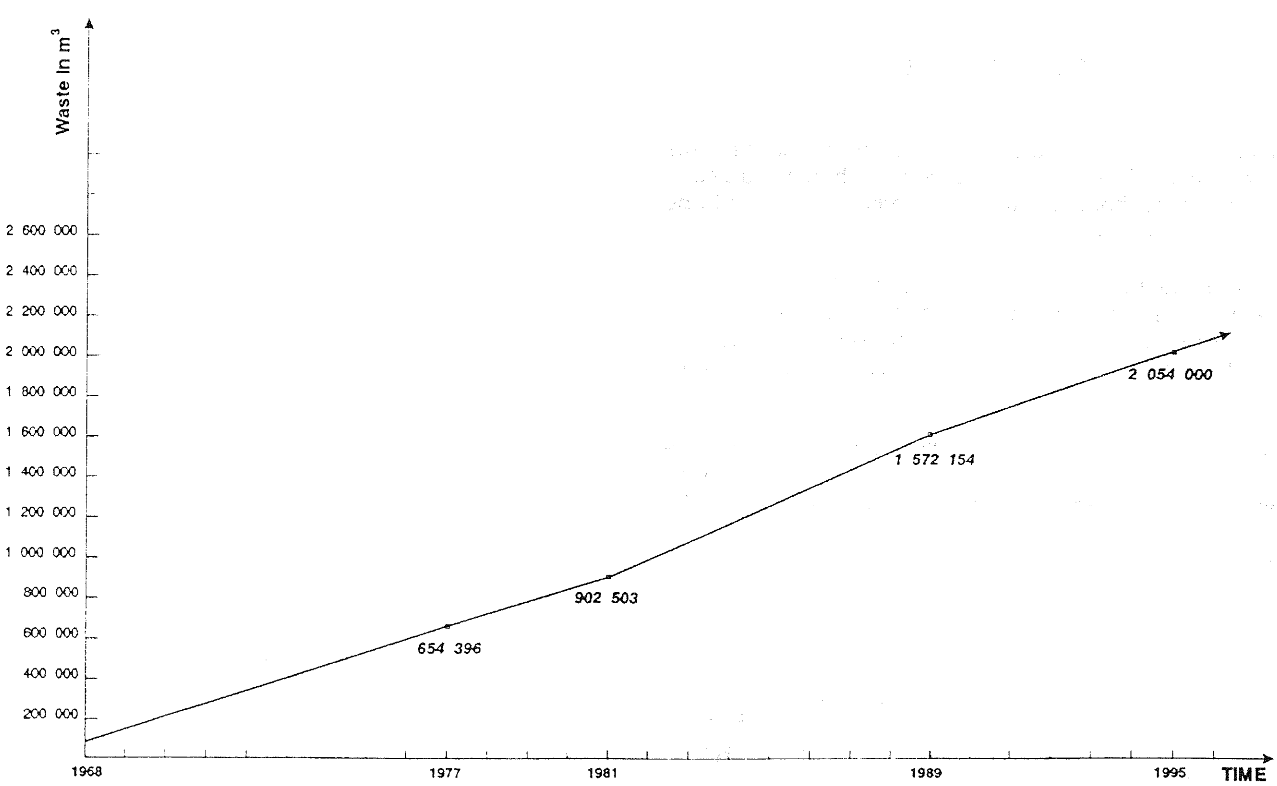


Figure 4: Averaged and extrapolated increase of the amount of waste based on stereo-photogrametric measurements

The data show an almost linear increase in the amount of waste deposited (Fig. 5).

During the period from 1968 to 1977 65.437,00 m³ per year have been deposited. In the next four years, from 1977 to 1981 the disposal of waste increased significantly to 225.626,00 m³ of waste per year, a trend which continued until May 1989. From that time on the amount of waste has been constantly increasing, reaching some 1000 tons/day in 1992 (Milanovic, 1992), which results in 313.000,00 m³ per year.

Based on the above data we can calculate that since June 1989 until the end of 1995, 2.054.000,00 m³ of waste have been deposited. So the total quantity of waste dumped at Jakusevec during the period 1968 to 1995 amounts to approximately 5.183.053,00 m³.

When precipitation infiltrates the waste dump where soluble components are dissolved and released, toxic water leaks into porous layers under the waste with aquifer layers where complex chemical reactions take place. The contaminated water advances through the aquifer and becomes purified, depending on the mineral, the granulometric composition, and the basic physio-chemical characteristics of the aquifer and the degree of poisoning.
Due to this filtering, no major contamination of the ground water in the wider Jakusevec area has been registered so far. Also, photointerpretation of the 1968 - 1989 aerial photographs shows that the health of the forests in the area has always been acceptable. There was no significant damage (drying), with the exception of the Canadian poplar, which, however, is not a native species.

## 4. CONCLUDING REMARKS

For the first time remote sensing methods have been applied in Croatia for the purpose of waste disposal site investigation. The multisensoral approach, making use of air- and spaceborne multitemporal data, turned out to be extremely efficient.

By airphoto interpretation it has been determined that at the very beginning waste has been deposited in river backwaters and gravel pits, thus causing direct contact with the ground water. This could have a negative impact on the ground water quality.

Finally it has to be concluded that remote sensing is a reliable tool for investigations on exising waste dumps as well as for the exploration of suitable new locations for waste disposal with respect to speed, precision and economy.

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