Key factors in sustainable planning policy for the dynamic shoreline of Herzliya, central Israel

RAM BEN-DAVID[1] & DROR NACHMIAS[2]

[1] *ROVED Geological Consultant. (e-mail: georoved@netvision.net.il)*
[2] *ADAMA Environment and Geology. (e-mail: drorn@adam-ma.co.il)*

Abstract: The cliffs running along the shoreline of the city of Herzliya are vital for the urban fabric of the city due to their unique landscape but are the source of planning problems due to landslide hazards or conflicts of interest. Plans along the cliffs and beaches must take into account the geological characteristics of these areas, the problematic sea /shore interaction (including the rising sea level), the influence of urban changes on the stability of the cliffs and the need for continuous free access by the public.

With this in mind, the main objective of this study was to define a directive policy for the development and conservation of the shoreline cliffs of the city. The need for such a directive policy is inherent in the Herzliya municipality's vision for this area, phrased as follows: "The existence of the shoreline cliffs, their wholeness as well as their continuity, are vital values for the city urban atmosphere. Thus, the planning and the development of the land use must be in accordance with sustainable planning principles."

This vision was defined as part of this study. In order to achieve this goal an assessment was made involving:

- Careful and detailed geological, morphological and hydrological studies to identify the geotechnical instabilities along the cliffs.
- Verification of the legal status of each plan and its influence on the cliff area to identify existing conflicts between the cliff zone and existing land use.
- Determination of potential future conflicts caused by new plans.

We then created objective long-term tools for planning new initiatives. These innovative tools, which will be detailed in the paper, were accepted by the city council and will serve, from now on, as guidelines for city planners and decision-makers when evaluating new project proposals.

Resume: Les falaises cotiere de la ville de Herzliya ont une importance vitale pour le tissu urbain de la ville due a leurs paysages uniques. Mais des hazards d'éboulement et des conflits d'interet crees des problemes de realisation de cette vitalite. Plans aulong des falaises et des cotes, doivent prendre en consideration le charactere geologique de cet environnement special, y compris – 1) l'interaction mer/cote, 2) le montant du niveau de la mer prevu, 3) l'influence de changements urbains de la stabilite de la falaise, et 4) l'acces libre pour le public dans toute sa longueur.

Avec ces idees, notre objectif principal a defini une directive politique pour le developement/conservation de la falaise cotiere de la ville d'Herzliya. La nessecite d'un plan de ce genre est inclue a l'agenda et a la vision de la municipalite de la ville qui en a ete defini par nous : "L'exsitence de la falaise cotiere, son entier, comme sa continuite sont des valeurs vitales pour l'athmosphere de la ville. Ce pourquoi, les plans et les developments doivent etre en accord avec les principes de plans durables".

Cette vision a ete une part de la definition de notre travail. Pour accomplir ces buts nous avons executer:

- Une etude detaillee sur la geologie, morphologie et hydrologie pour identifier les instabilisations geothechniques lelong des falaises.
- Verifications du statut de chaque plan, son influence sur l'environnement de la falaise cotiere et des possibles conflits entre la zone falaisienne et l'usage de la terre.
- Determination de conflits futurs dus aux plans nouveaux.

Ensuite, nous avons forme de nouveaux long terme outils pour les plans d'avenir. Ces outils ont ete accepte par le conceil de la municipalite et ils vonts servir comme guide pour chaque decision qui va influencer l'environnement de la falaise cotiere.

Keywords: friction angle, geomorphology, mechanical properties, erosion, shorelines, slope stability

INTRODUCTION

The coastal cliffs of the city of Herzliya (Figure 1) provide a valuable landscape for the character of the city but are also an endless source of concern due to unstable slopes and planning conflicts. The municipality plans along these cliffs must take into account the prerogative of the public, the interest of entrepreneurs and landscape planning and risks due to the geological characteristics of the cliffs. Herzliya's mayor and environmental division initiated this study to aid decision-making "to receive an objective policy for the development/conservation of the seashore cliffs within Herzliya's responsibility." In order to achieve this goal we divided the study into four subtasks:

- Identification of the stability of the seashore cliffs: a detailed study of the geological and geomorphological features was carried out. Geotechnical information was then added to provide engineering tools for future decisions;

- Identification of existing conflicts of land use along the seashore cliff areas: a careful study of all the designated terrains and potential conflicts;
- Identification of potential future conflicts based on the above-mentioned information;
- Creating objective tools for planning in these areas for the municipal decision makers.

Figure 1. Location map.

GEOLOGICAL AND GEOTHECHNICAL CHRACTERISTICS OF THE SEASHORE CLIFFS (SSC)

General overview of the topographical and geological characteristics

The topography of the SSC is characterized as follows:

- The seashore's width varies from a few meters to several tens of metres trending N-S in an almost straight line. The clear yellowish quartz sand comprising the shore rises gently to about +2 m at the cliff's foot. The shore is very narrow (only a few meters wide) at the northern end and widens to more than 100 m at the central part due to the Herzliya marina and due to breakwaters several tens of meters from the natural seashore. South of the marina, the shore has preserved its original width, which is about 40-50 m. The shore characteristics are of great importance in light of the ~0.5 m rise of the sea level over the last 40-50 years.
- The cliffs rise sharply to between +15 m to +30 m with a slope ranging between 70^0 and 90^0. In a few places the slopes overhang, forming a cave-like recess parallel to shore.
- The cliff's top forms a wavy plateau, sloping gently eastward (Figure 2).

Figure 2. General view of the cliff and seashore topography.

The geology of the cliff section is composed mainly of five Upper Pleistocene sandstone units (locally called Kurkar) and clay sand soils (locally called Hamra), which were deposited probably as near-shore dunes (e.g. Gvirtzman, 1984). Their age ranges, by OSL dates, from ~60 KaBP to ~5KaBP (All datings were performed by Porat & Wintle, 1994 and Rita, 1998 using Optically Stimulated Luminescence (OSL) and Infrared Stimulated Luminescence (IRSL). The dynamic processes occurring along the SSC are due to the regression and ingression of the Mediterranean Sea during the climate changes of the Late Pleistocene. The seashore is coved by yellowish quartz sand which accumulated due to northward and northeast sea currents transporting sand from the Nile cone (e.g. Almagor et al., 2000). The five geological units recognised in the cliff succession are as follows: (from bottom to top – Figure 3):

Unit A: The Kurkar Ramat-Gan (also: Unit II in - Wiseman et al. 1981)

It is composed of Kurkar layers, cemented by $CaCO_3$ (40-60%) and is characterised by its sheet-like cross bedding, reinforced by the partial cementation (Figure 4). It also contains bioclastic grains of marine and coastal fauna. The cementation among the cross-bedding sheets enables the existence of vertical walls at the cliff's feet. While its base is not exposed, its top is formed of undulating outcrops of 9-22 m. The unit's age is 57-58 KaBP and the sedimentology suggests that it was deposited as a near-shore dune during a period of a much lower sea level.

Unit B: The Nachshonim Unit (also: Top Unit II in – Wiseman et al. 1981)

This unit is composed of silty-sand, poorly cemented with $CaCO_3$. At its upper part the unit contains pedogenic nodules and continental snail shells (*Helix*), indicating its inland dune origin. The thickness of this unit is 1-5 m.

Unit C: The Dor Unit (also: Unit III in - Wiseman et al. 1981)

Sedimentologically the Dor Unit closely resembles the Ramat-Gan Unit. The main difference is in the amount of $CaCO_3$ cementation, which is about 5-15% of the total mass. The unit's age was determined to be 48-53 KaBP and the thickness of this unit varies from 3 to 10 m, filling the underlying relief.

Unit D: The Netanya Unit (also: Top Unit IV in - Wiseman et al. 1981)

This unit is a palaeosol composed of brownish-reddish sandy-loam with $CaCO_3$ nodule concentrations. The clay fraction includes montmorilonite, which causes changes in the cohesion due to seasonal water content. The contact with the underlying Dor Unit is mostly gradual while its top is sharp. Its thickness is 2-8 m representing an inland stable period and its formation age (based on OSL and archaeological artefact) is estimated to be Epipaleolith (13-56 KaBP) (Ronen, 1977; Rita, 1998).

Unit E: The Tel-Aviv Unit (also: Top Unit V in - Wiseman et al. 1981)

This unit is composed of medium to coarse quartz sandstone and is well cemented by $CaCO_3$ reaching up to 40% in volume. The source of carbonate forming the cement has mostly originated from bioclastic fragments and primary precipitation. Its top forms a plateau, waving gently, some 20-30 m above sea level.

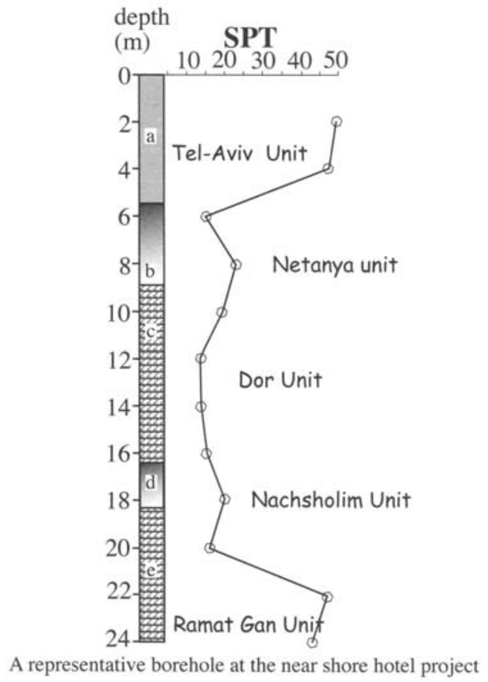

Figure 3: Composite geological section with representative SPT values for each unit (a-e) (from: Ben-David & David, 1998).

Some geomorphological observations (from Ben-David & David, 1998)

Longitudinal caves due to sea waves

The beach area is active during most of the year. Its activity consists of sand accumulation and erosion, tides and changes according to wave amplitude. During periods of high tides and storms, the waves can reach the foot of the cliffs forming caves parallel to the seashore (Figure 4). These intensive erosional caves are mostly filled up again with sand.

Figure 4. A close look at the page-like Kurkar and a longitudinal cave at the cliff's foot.

Reduction of cohesion

Infiltration of water and salts into the cliff's surface and the rain splash cause dissolution of cement and removal of particles (Perath & Almagor 1996). These phenomena reduce the resistance of the cliff's face to a depth no greater than a few meters. This process is supported by the geometry of the landslides and is explained below.

Upper Kurkar layers instability

Collapse of blocks from the upper cliff in the Tel-Aviv unit is due to the presence of water in the Netanya unit, which causes weathering and reduction of cohesion leading to the erosion of soil pads. This leads the Tel-Aviv unit to overhang and ultimately results in the gravitation fall of blocks onto the seashore.

Surface runoff

The natural runoff from the water divide to the beach runs on high gradient (15% or more). Human activity, especially in this urban surrounding, increases the water damage by two major factors – 1) the amount of surface water run off is increased due to lower infiltration rates and 2) the surface water velocity is increased due to the reduction of water friction along the paved areas. These processes increase the erosion of the cliffs, forming gorges, creeks and hanging blocks.

Landslides

Landslides occur due to the combination of the factors mentioned above. They are not longer than 20 m wide and 3 m deep and they occur mostly at the end of the winter. The geomorphic characteristic as well as the reduction of the total strength of the outer part of the layers enables the removal of blocks and movement of the earth mass downward. The result of these activities is cliff recession, which is averaging a rate of 0.2-0.5 m per year.

Table 1. Summary of geological and geotechnical parameters of the SSC (fig. 3).

Geol. Unit (a)	**Tick.** (m)	**Slope angle** (^{0})	**OSL dates** (KaBP)	**Texture**	**Poros.** (%)	**Humod.(%)** Before Rain	After rain	**Cohes.** C kPa	**Ang. int. fric.** • ^{0}
source		(b)	(c)&(d)	(e)	(f)	(g)		(h)	(h)
***K. Tel-Aviv**	0-5	80-90	5-10	Sand	30-50	0.5		170-600	38-45
Netanya	2-8	20-90	13-56	Sandy clay		2	23	10	35
K.Dor	3-10	30-50	48-53	Sand	4-32	0-3	8	0	35-37
Nachsholim	0-3	60-85	50-57	Silty sand					55-90
K.Ramat-Gan	4-22	6-90	57-58	Sand	2-23	7.5	30	30	33-43

*K. = Kurkar (arenite sandstone, carbonate cementation)
(a) Gvirtzman et al. (1984); (b) Wiseman et al. (1981) and this work; (c) Porat & Wintle (1994), Rita (1998); (d) from Epipaleolithic finds (Ronen 1977); (e) definition from Birkland et al. (1991) method; (f) Porath & Almagor (1996); (g) Yaalon & Larrone (1971); (h) Wiseman et al. (1971).

Geotechnical characteristics of the geological section

Table 1 summarises the geological and geotechnical characteristics of the cliff units. Some remarks can be concluded from this table:

- There are large variations of internal friction within the same unit.
- Considerable cohesion is found only in the Tel-Aviv unit.
- Large changes occur in the humidity capacity of the near slope surface due to the high infiltration rates.
- The changes of humidity content reflect the geomorphological processes that lead the most probable portion of the cliff to slide.

THE STRATIGRAPHY OF THE HERZLIYA SSC FOCUSING ON LOCAL NATURAL AND ARTIFICIAL EROSION AND DESTRUCTION

General perspective

The thickness of each geological unit changes radically along the SSC, especially the lowest one – Kurkar Ramat-Gan. The fact that there are characteristic variations within a particular geological unit cause different timing and sizes of a single landslide event to occur.

Reasoning of the division of the SSC to segments and the semi-quantitative method

Due to the above-mentioned differences, intensive effort was made to divide the SSC into segments according to objective criteria. Differences in geotechnical properties between the units do not seem to have much influence on cliff stability. The importance of each criterion was decided based on its influence on the cliff's stability. The criteria and their relative importance were determined to be as follows:

- Width of shore – 30%;
- Elevation of the cliff plateau – 15%;
- Topographic slope angle – 10%;
- Runoff to the cliff slopes – 25%;
- Construction near cliff's head – 10%;
- Artificial cover of the slopes – 10%.

Each segment was ranked according to its local contribution to the instability using a rating of 1-5, where 5 is the most/least influential respectively. This enabled us to evaluate the stability of the cliffs by a semi-quantities method of each segment. The specific rank multiplied by its relative importance enabled us to calculate the total instability of a certain SSR portion.

The SSC segments

The results of applying our new evaluation method enabled us to divide the total cliff length into 11 segments. The main data for each segment and their rankings are summarized in Table 2. The total sum determines whether a particular segment carries high (H = 0-50), medium (M = 51-70) or low (L = 71-100) instability rate.

Table 2. Semi-quantitative evaluation of the SSC's segments stability as reflected in the defined parameters evaluation accompanied by its rank. In parentheses are the specific calculated results.

Segment (from North to South)	Shore width (m)	Cliff head elevation (a.s.l.)	Cliff slope	Near SSC Construction	Runoff Towards SSC	Existence of artificial cover	Total rank	Inst. evaluation
TA'AS area	1(6)	1(3)	1(2)	5(10)	1(5)	1(2)	28	H
N. Apolonya Antiquity Park	1(6)	1(3)	1(2)	2(4)	1(5)	1(2)	22	H
S. Apolonya Antiquity Park	1(6)	2(6)	2(4)	3(6)	2(10)	2(4)	36	H
Sidna-Ali and the villa street	2(12)	1(3)	1(2)	2(4)	3(15)	1(2)	37	H
De-Shalit Square	3(18)	5(15)	5(10)	2(4)	3(15)	5(10)	72	L
Hotel area – north	3(18)	3(9)	3(6)	1(2)	3(15)	4(8)	58	M
Hotel area – south	5(30)	3(9)	3(6)	1(2)	3(15)	5(10)	72	L
Marina entrance gap	5(30)	5(15)	5(10)	4(8)	2(10)	3(6)	79	L
Marina and Tel Michal antiquities	5(30)	3(9)	2(4)	2(4)	4(20)	1(2)	69	M
Marina outlet road	5(30)	3(9)	3(6)	3(6)	2(10)	2(4)	65	M
Southern Herzliya cliff area	3(18)	3(9)	3(6)	5(10)	3(15)	1(2)	60	M

The TA'AS area

This segment is 0.23 km long and the shore is on average 10 m wide. The cliffs are almost vertical and rise to about +32 m. A former industrial zone used to deliver polluted flows to the sea through a topographic saddle that ultimately turned into a deep creek. The geological section there is composed of a thick low cohesive section.

North Apolonya Antiquity Park (Figure 5)

This area, 0.32 km long, consists mainly of crusade fortress ruins, which were built upon older civilizations. Its western part includes a small anchorage and a continuous wall prevents the cliff's collapse. These ruins were almost intact until about 1940. Today, most of this protective wall has been destroyed and only a few parts near the northern moat still exist. The shore is very narrow, only few meters, and much of the sand has been washed away. Runoff flows through the peripheral moat have caused erosion trenches.

Figure 5. The Apolonya antiquities and the cliff stability problems.

South Apolonya Antiquity Park

This area, 0.15 km long, consists mainly of a low cohesive geological section. The very narrow Herzliya shore, as well as runoff from the upper plateau cliff, causes its rapid withdrawal. Evidence indicates that some 50-80 years ago the shoreline was some 10-20 m west of the present one.

Sidna-Ali and the Villa Street

Sidna-Ali is a mosque situated upon the plateau several tens of meters from the cliff's head. It is a residential neighborhood, 1.1 km long, where the backyards touch the cliff's head. The relatively strong resistance of the Kurkar Ramat-Gan forms the rather vertical, occasionally negative overhanging cliff topogarphy rising to about +22 m. This cliff's characteristics cause fewer slides but when they occur they are of a greater magnitude. Irrigation, which sometimes evolves to underground flows or runoff, accelerates the withdrawal of the cliff.

The De-Shalit Square

This area, 0.2 km length, used to be a topographic saddle and natural channel. Today it is the major access path to walk down to the seashore. It is almost totally paved – therefore very stable.

The Hotel area – North

Along this segment, 0.88 km long, hotels that were built on the sea cliff replace most of the natural landscape. The width of the shore reaches almost 60-70 m due to influence of the breakwaters south of this segment. In extreme storms waves can reach the cliff's foot.

The Hotel area – South

The chain of cliff top hotels continues southward for 0.7 km, leaving almost no exposures of the natural sections. As mentioned above, breakwaters reduce waves to a minimum. In the southern Hotel section this has caused the accumulation of sand. This situation stabilised the cliff but its original landscape has been destroyed.

The marina harbor entrance gap

This area, 0.3 km wide, used to be a river channel that drained from great distances. During ancient times the Romans used this channel to drain swamps through a tunnel in a section of Kurkar ridge, far to the east. Today it is a flat area, which serves as the main entrance to the marina. The main drainage pipe of the entire city was built below this section. Although it is a stable area, the drained water prevents the local accumulation of sand at the shore.

The marina and Tel (archaeological hill) Michal antiquities

The cliff within the Herzliya marina rises to about +20 m along 0.38 km. Excavations for the marina's construction and efforts to preserve the archaeological site forced construction along part of the exposed retaining wall. The disconnection between the sea waves and the cliff prevents, of course, any erosion due to them. But the total stability along the parts that are not retained is rather low because of the low strength of the Kurkar.

The marina outlet road area

The southern marina outlet, 0.35 km long, consists of a thick brown sandy-clay (from the Netanya Unit) and occupies most of the cliff, forming a dense dendritic first order drainage system, left as a topographic low of the former relief. Here, there is no connection between the sea waves and the cliff remains, therefore erosion sources are mainly runoff. Road construction, however has conserved only a small portion of this section's natural appearance.

Southern Herzliya cliff area

This area, 1.17 km long, is actually the most intact portion of the long Herzliya shore and cliff. The cliff is rather shallow at around +17 m above sea level, and the geological situation forms a stable slope, ranging from 60-70^0. The land use reserves are under pressure from entrepreneurs, and therefore this policy statement is of a great importance for the future development of the area.

CONSERVATION SUGGESTIONS FOR THE SSC

We have suggested application of some principals to preserve the maximum natural appearance of the cliff, to leave the cliff and the shore open to the public and to prevent any danger along unstable areas. Our suggestions include the following measures:

- Prevent the sea wave from arriving to the cliff's foot;
- Prevent any runoff from flowing along the plateau at the cliffs head;
- Reduce lateral forces along the cliff head by reinforcing the natural layers (e.g. using piles);
- When necessary, reduce the slope angle;
- Use stabilising plants;
- Continually survey the cliffs to enable identification of changes and quick implementation of engineering intervention measures;

- Prevent swimming pools from being built near the cliffs;
- Irrigate along the cliff areas with drip irrigation systems only.

MUNICIPALITY PLANNING AND THE SSC

Approaches

The approach adopted by the municipality was decided upon due to local political pressure to ensure public use of the seashore area and determined after studying policy examples from other places. Each country, region or area tries to find solutions to the problem within their planning ability, local laws and political pressures. In Israel the Society for Protection Nature (SPN) has tried for many years to convince the decision makers of the importance of this environment for the public's sake. They published "The sustainable planning principles for urban seashore – a statement viewpoint," (SPN, 1999) suggesting 3 principles – 1) the seashore and its environment (at least 100 m wide) is public property and therefore should be available to all, 2) the authorities must develop these areas according to sustainable principles, including the protection of all natural and cultural values, and 3) the local authorities are responsible for the maintenance of the shore. These values are the main trend of many other environmental organizations (e.g. Papai, 2000; Firestone & Hann, 1998; Raz & Nesher, 1998).

Summary of the planning situation in Herzliya

After analyzing the principle municipal documents and interviewing the main decision makers regarding city planning along the seashore and cliffs, we concluded that no coherent policy exists. We therefore examined each relevant plan with regard to the municipal and/or state regulations. For example, the municipality gave a permit for construction of the Cliff Hotel, although eventually it replaced the entire cliff with concrete (Plan - HR/665). It is clear that the main focus in the future will be on the area south of the Herzliya harbor, which is still open to development. There the value of the land is considered to be very high and such a mistake will not be repeated.

RESULTS – A SUSTANBLE POLICY FOR PLANNING THE SSC AREA

General principles

For the sustainable planning policy to be useful the municipality must, first of all, accept a new vision for the shore and cliff area. The accepted vision was: "The existence, wholeness and continuity of the Seashore Cliff are of great urban value. Therefore, planning and development at its urban nape and its shorefront will be under sustainable principles. The ambition is that all people will have free access along the entire cliff area, and all necessary measures to prevent danger to life or property losses will be implemented."

Policy for the entire cliff

The vision mentioned above was enhanced to add the following details:

The cliff values

- The seashore belongs to the public and free access must be maintained;
- The cliff is a precious landscape value to the city and to preserve it special care will be taken when planning and constructing near it;
- A free pedestrian way along the cliff's head must be planned. In places where it can not be achieved, creative solutions must be found;
- The natural cliff landscape should be guarded and any damage to it must be prevented.

Possible protection measures along the cliffs

- All land users near the cliff's vicinity are responsible for preventing any public hazard;
- While applying for a construction license one should give attention to the following issues: drainage and sewage plan, pools and reservoirs, gardening plan (all to prevent any leaks to the cliff) and organization of the construction area (to prevent any earth piles or cause agitation near the cliff);
- All aspects of every project will be subject to sustainable and esthetic planning;
- All engineering actions, such as stabilization measures, will not deviate from the particular project area.

Some main planning perspective remarks

- A pedestrian and bicycle trail along the cliff's head will not change its natural appearance and no new routes will be created;
- Any new project in the vicinity of the seashore cliff will be subject to Public Collaboration.

- The design of the drainage system will be of a frequency of 1% (a 1 to 100 year event);
- The runoff will never be directed to the cliff area and it will be planned with a 2% eastward direction (opposite the cliff) to the main collection system.

Guidelines for planning and ground action

Geological, geomorphological, geotechnical, environmental needs as well as state and municipal regulations provided the motivation for a well-defined directive document for future planning policy for the areas surrounding the seashore cliff.

Instructions for the ground actions are provided separately for the 11 segments previously defined, and they include the following descriptions made available to entrepreneurs, architects, civil engineers and all necessary decision makers from the municipality:

- General segment description – topography, geology, etc.;
- Landscape sensitivity – from high to low;
- Geotechnical sensitivity;
- Recommended seaward construction limits (distance from the cliff's head);
- Guidelines for terrain development and control tools;
- General remarks.

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Corresponding author: Dr Ram Ben-David, ROVED Geological Consultant, 10, Gefanim St. PO Box 98, Sarigim, 99835, Israel. Tel: +972 2 9991949. Fax: +972-2-9991950. Cell: 972-50-5350293 Email: georoved@netvision.net.il.

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