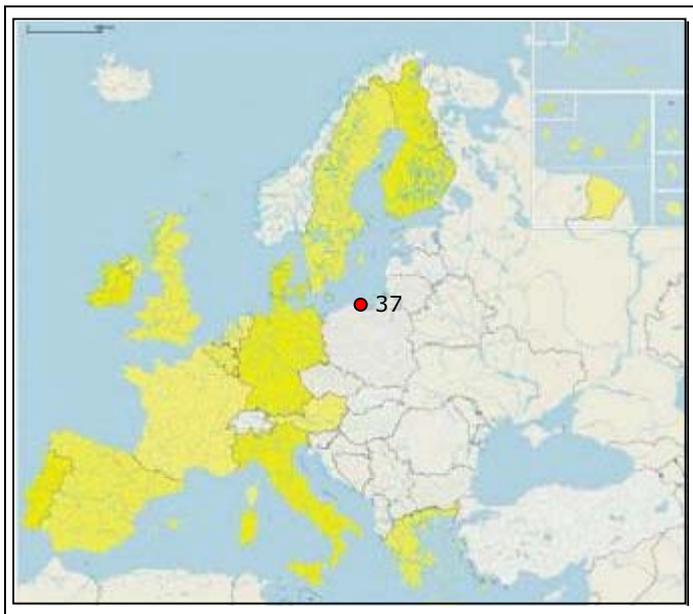

HEL PENINSULA (POLAND)



Contact:

Kazimierz FURMANCZYK

**University of Szczecin
Institute of Marine Sciences**

Felczaka Str. 3a
71-412 Szczecin (Poland)

Tel: +48 91 444 1600
Fax: +48 91 444 1600

e-mail: kaz@sus.univ.szczecin.pl

1. GENERAL DESCRIPTION OF THE AREA

The Hel Peninsula it is 36 km long sandy spit situated at the western part of Gdansk Bay at southern Baltic. The Hel Spit is long, narrow, low, relatively flat and very suitable for erosion. The area of interest in this case is the first 25 km of the spit from the root. This part is very narrow (most 300 m) strongly eroded when harbour was founded at the beginning of spit, and longshore transport of sediments was broken. There are a number of works on the geology, geomorphology, and dynamics of shore processes observed along this section of the coast (Basinski 1995, Furmanczyk,1995, Musielak 1989, Rosa 1963, Tomczak 1995 and others).

1.1 Physical process level

1.1.1 Classification

Based on classification of coastal system (©EUCC 1998) on the study area dominant landscape type is wave-dominated sedimentary plains with dune coasts in microtidal zone. On the study area coastal zone exist a spit-dune coast built of Holocene deposits.

1.1.2 Geology and development of the region

Hel Peninsula has evolved during the Holocene. Its coast is basically of recent alluvial and littoral zone Holocene sediments from 10 to about 100 m thickness (Fig.1.1.).

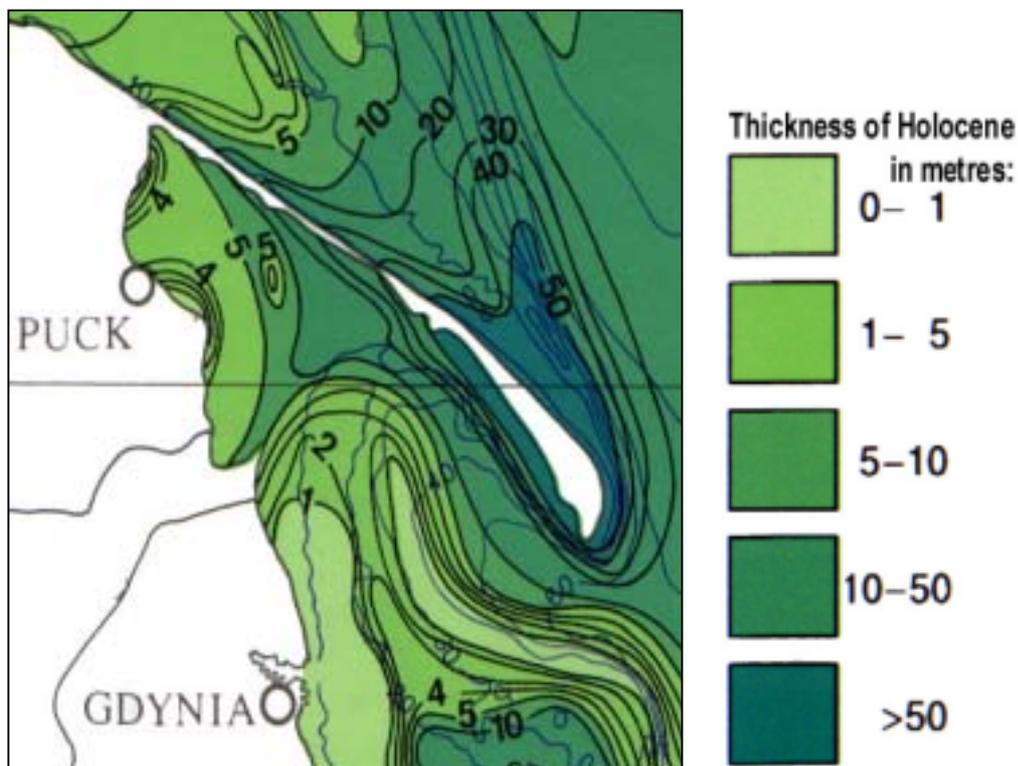


Fig.1: Thickness of Holocene deposits. Source: Geological Atlas of the Southern Baltic, 1995.

Pleistocene and Holocene deposits occur on the whole length of the study area, on the land and on sea bottom (Fig.2).

The study area coast is 25 km long spit with dunes from 2-3 to 10 m high, and at some places reach the height of 13 m above sea level. Behind the spits there is the Puck Lagoon and a part of Puck Bay. Puck Lagoon it is a relatively wide depression of glacial or glaciofluvial origin, with depth from 1 to 5-6 m. The part of Puck Bay that is connected with study area is shallow 2km wide area with a depth not exceed 2m (Fig.3).

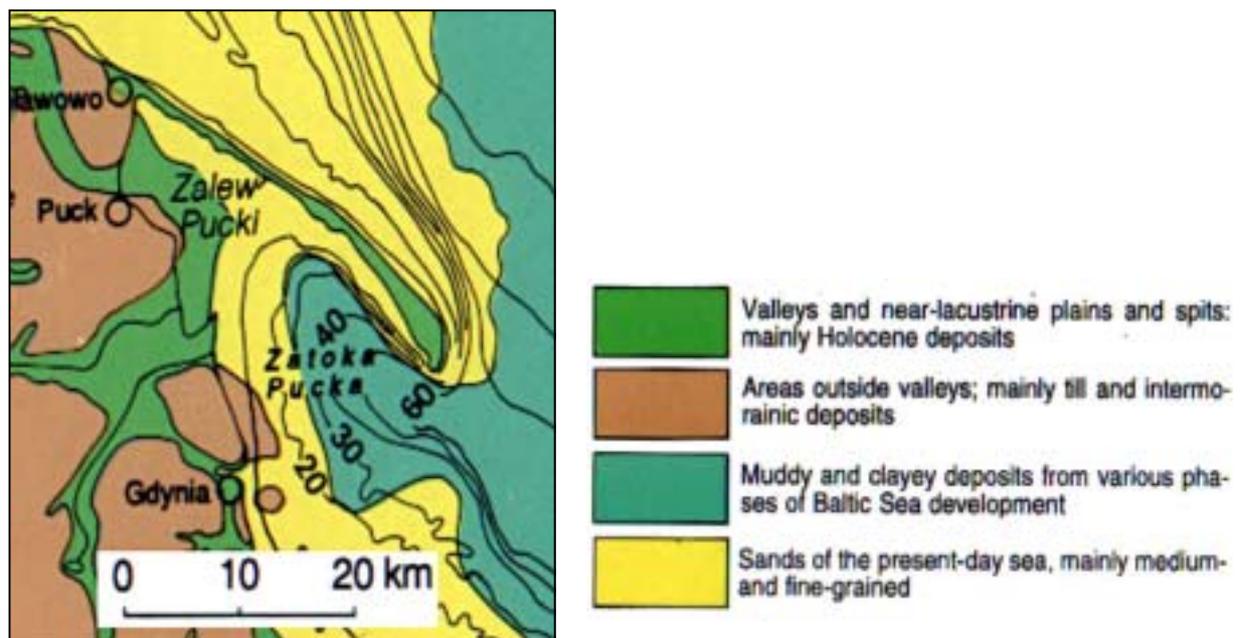


Fig.2. Outline of relief and lithology. Source: Geological Atlas of the Southern Baltic, 1995.

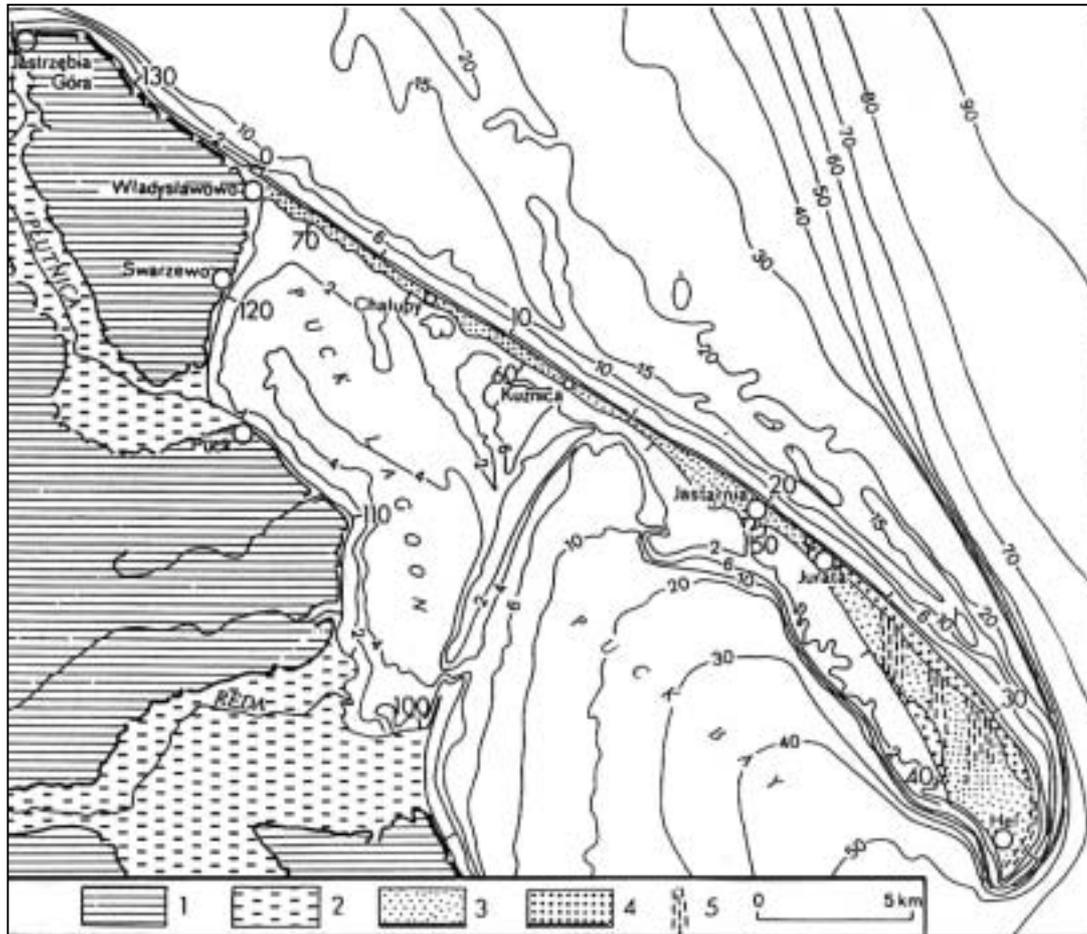


Fig. 3: Hel Peninsula: Elements of geomorphology on the background of bathymetry of the surrounding sea. 1- morainic plateau, 2- pradolina floor, 3- peninsula area covered by low aeolian forms, 4- area covered by high foredunes, 5- storm ridges slightly reshaped by the aeolian processes. Running kilometres of the Polish shoreline are marked from east to west; running kilometres of the Hel Peninsula are marked separately (Tomczak 1994).

The geological structure of the study area presented geological cross-section along the spit coast (see Fig.4).

Pleistocene deposits on this area are present in the substratum of the whole spit. However they are in two horizons, they lie higher at the root, and lower near the tip of the spit (Tomczak 1995). Holocene series is fully developed only in the east part of the spit, where its thickness reaches 100 m. In the study area (west part of the spit) there are Holocene deposits only of the Litorina period, forming a relatively thin cover 10-12 m thickness.

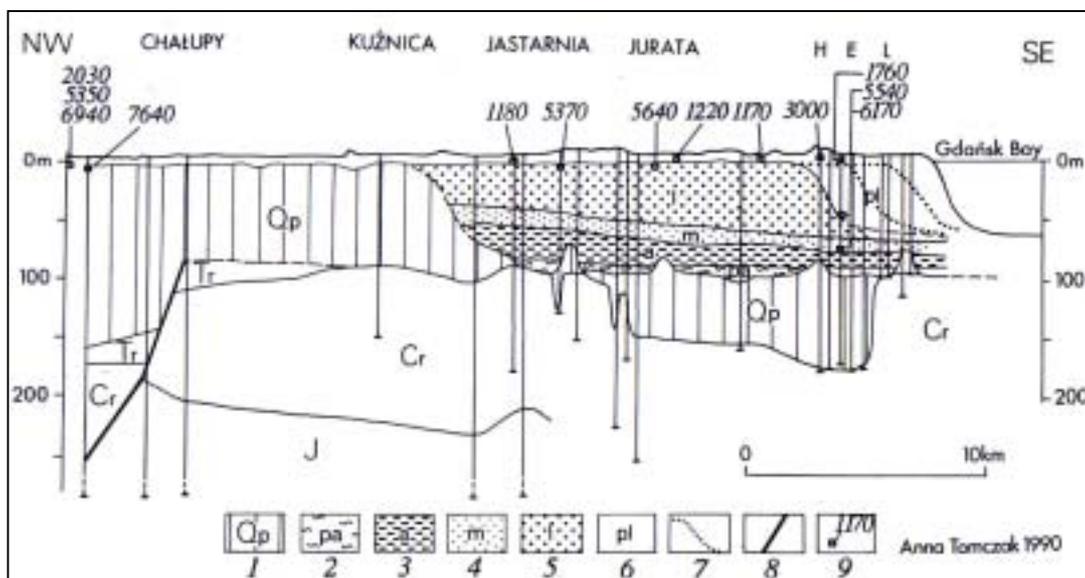


Fig.4: Simplified geological cross-section along the Hel Peninsula. J-Jurassic, Cr-Cretaceous, Tr-Tertiary, 1- Pleistocene undivided; Holocene deposits: 2- Pre-Ancylus, 3- Ancylus, 4- Mastogloia, 5- Litorina, 6- Post-litorina, 7-accretion-lines of the youngest part of Hel Peninsula, 8- fault, 9- selected sites with ^{14}C dating (Tomczak 1994).

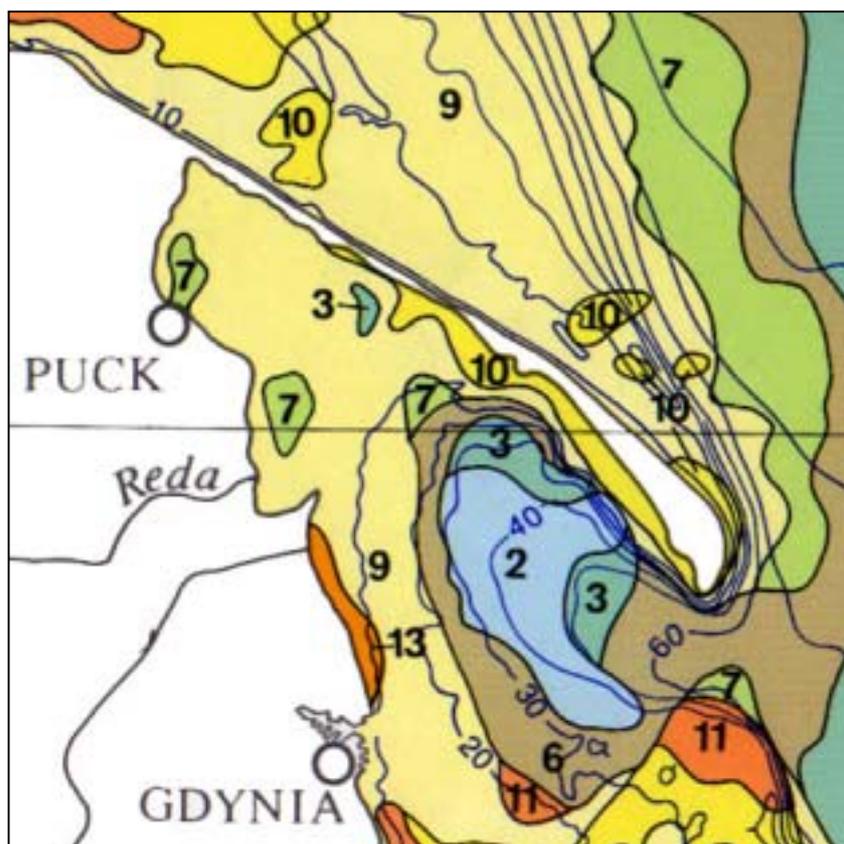


Fig. 5: Surficial bottom sediments: (2) silty clay, (3) clayey silt, (6) sand-silt-clay, (7) silty sand, (9) fine-grained sand, (10) medium-grained sand, (11) coarse-grained sand, (13) vain-grained sand. Source: Kramarska 1995.

Sediment characteristics

Beach and bottom sediments in the pilot area are of siliciclastic origin (sand, gravel) and have a light (white) colour. The sand grain size is fine, medium to gravelly sand, changing along the beaches and the outline (Fig.5.).

1.1.3 Morphology

The beach is existing along whole study area. The width of the beach is various from 25 to 65 m. The mean beach width calculated for the study area is about 40 m.

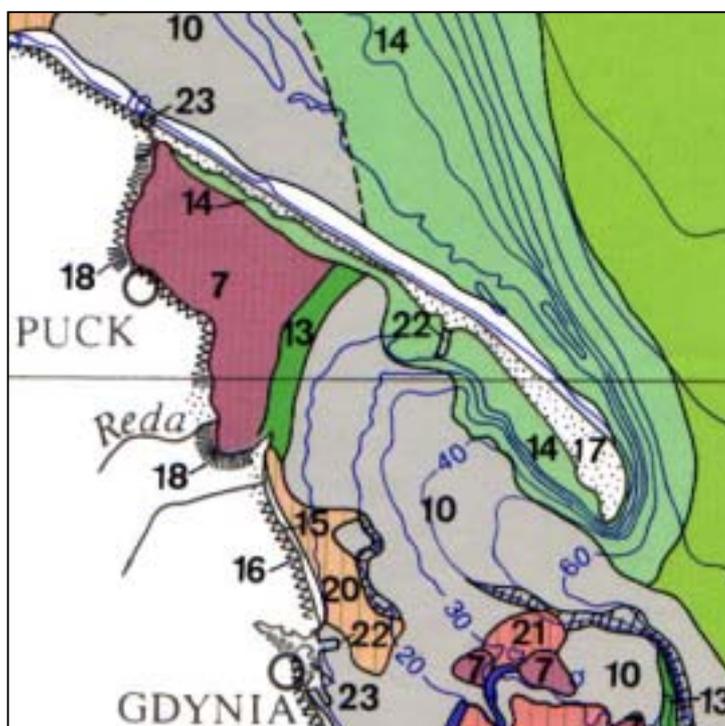


Fig. 6: Morphogenesis sea bottom. Relicts of forms of terrestrial origin: (7) peaty-limnic plains, (8) paleo-channels; forms of marine origin: (10) erosion- aggradation plains, (13) relicts of aggradation coasts, (14) split slope; forms of recent coastal zone: (15) recent coastal slope, (16) cliff coasts, (17) dune coasts, (18) alluvial coasts. Source: Pikies 1995.

Along the study area coastal zone bathymetry varies. The 15-m isobath runs 4 km from the shoreline near Wladyslawowo approaches the coast at a distance of 600 m near Jastarnia. There is existing underwater longshore bar system along the whole study area. There are usually 2-3 bars in front of coast. Part of the study area coast about 12 km long is protected by groins.

Typical profile of the spit is presented at Fig.7.

1.1.4 Physical processes

Winds of the Southern Baltic are the predominance of SW and W directions, throughout the year and in most months, with the exception of spring.. The percentage of situation with wind above 6 degrees Beaufort is highest in the period from October to March, and exceeds 15-20% in particular months.

In the coastal zone, the highest mean monthly wind speeds ($5-7 \text{ ms}^{-1}$) are characteristic for the autumn-winter months, whereas the lowest are recorded from May to August ($2,5-3,5 \text{ ms}^{-1}$), when the Baltic Sea basin is characterised by low pressure gradients. The autumn-winter season contains the greatest number of days with strong winds. The frequency of stormy weather (above 8 Bft) can be from 2 to 5%, depending on the month and area (Zeidler at al., 1995).

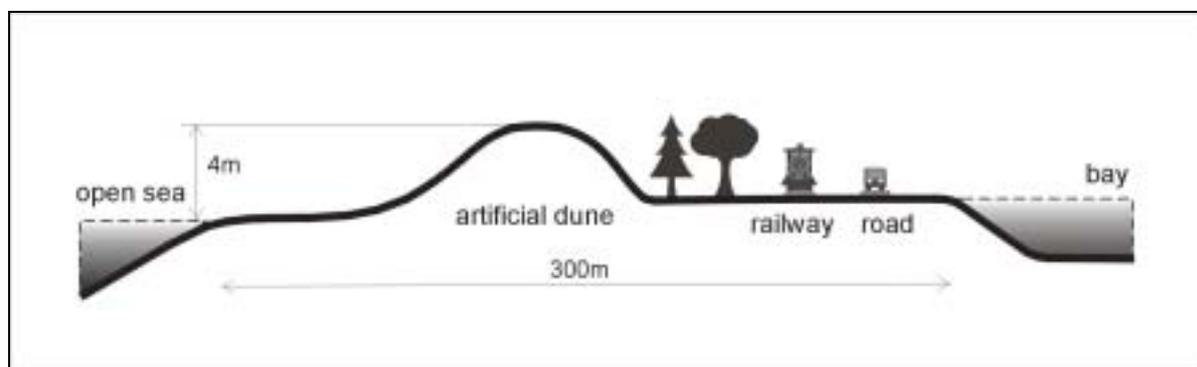


Fig.7: Typical profile of the beginning part of the Hel Peninsula.

Strong wind from N-NE direction is the most affected the study area. The highest waves 8 m high were observed when N direction wind strongest than 20m/s was existing more then 2 days. Together with high storm surges and baric tide it could be a catastrophic storm for the spit. The astronomic tidal regime is very low about a couple of centimetres.

The wind from direction N-NW causes coast erosion: by waves and create a longshore transport of sediments towards the end of spit. This is a very unfavourable situation for the coast of the root of spit. Unfavourable are also winds from NE direction, that is direction perpendicular to spit. In this situation are activated the circulation cells accompanying the coast erosion. Ripcurrents appearing every 120 m and the higher generation of circulation systems create crossshore currents through the gates every 3-6 km (Furmanczyk, Musielak 1999). These currents transport sandy material eroded from the coast into deep water.

Favourable for the beginning part of Hel Peninsula is strong wind from E-SE direction. Although it cause the erosion of widest, end part of spit, but it activate longshore transport of sediment towards the beginning section of the spit root.

Sea level rise

Recent examination of trends and statistical distributions in sea level datasets, revised and updated for the Polish coast, has partly confirmed some earlier conclusions drawn for mean sea level (and exposed new findings for extremum sea levels). The trends given in Table 1. have been established for ten Polish tide gauge stations in the period of 35 years.

Table 1. Sea level at the eastern Polish coast stations: mean values and rise rate for the years 1951- 1985.

Station	Mean sea level	Growth rate, mm y ⁻¹
Władysławowo	499,5	1,7
Hel	501,4	1,7
Gdynia	502,9	2,2
Gdańsk- Nowy Port	504,0	2,9

Note: Tide gauge zero= -500 cm NN₅₅ (Amsterdam) = -508 cm H_r (Kronshtad)

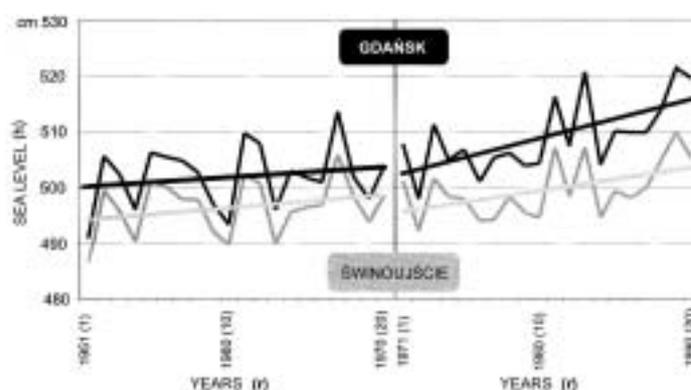


Fig.8: Accelerated sea-level rise and its components at the Polish Baltic coast in the years 1951- 1990 (Rotnicki K., Borzyszkowska W. 1999).

These trends should be looked at longer time scales, such as those dealt with by Dziadziuszko & Jednorad (1988) for Gdansk (from 1886), always to 1985. The multi-yearly mean sea level for those periods assumes the following values: Gdansk- Nowy Port 500,1 cm \pm 0,5 cm. (Fig. 8). Effect of expected sea level rise is presented as a diagram at the Fig.9.

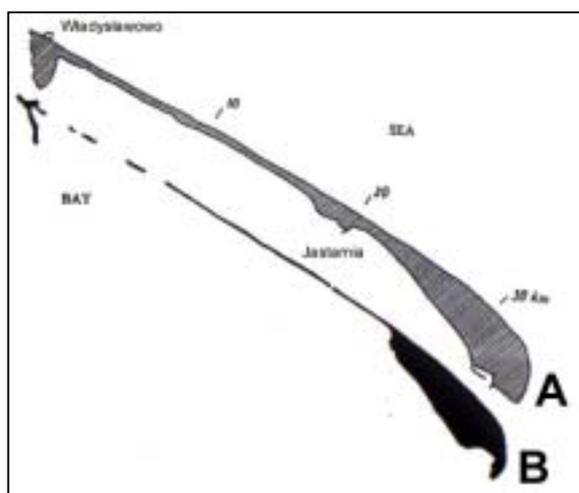


Fig.9: Effect of expected sea level rise and storm surge on the shape of Hel Spit; A- mean sea level, B - +2.5 m. (Basinski 1995).

1.1.5 Erosion

Inputs and outputs of sediment

There is one main source of sediments in the coastal zone of the study area – it is coastal erosion. In the coastal zone there are sediments as an active forms of sea bottom, beach and dunes. Erosion, accumulation, transformation and redeposition of sediments located in the coastal zone is provided by water influence (waves, currents, surges) on the bottom and on the beach and also by wind influence on dunes and beaches.

A general sedimentary process in the area is presented at Fig. 10.

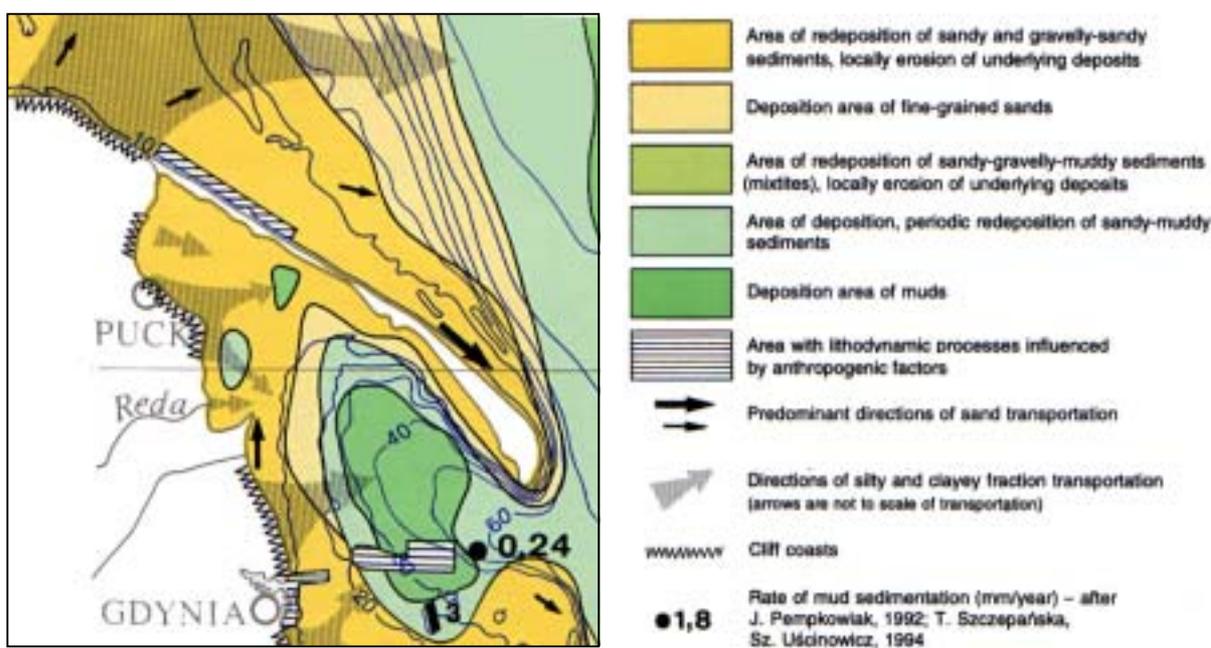


Fig.10: Recent sedimentary processes. Source: Uścińowicz 1995.

Coastline variation and eroding sites

The coastal evolution was calculated on a base of air photographs analysis done by authors (Furmanczyk, Musielak 1993). Classification of Hel Spit coast's changes in period of times 1957-1991 years was presented as a diagram at the Fig.11.

In the analyze of the long-term tendency in the development of the Hel Spit coastline, as well as their dynamics are visible, that the western part of the Spit (study area), despite its coastal protection in the form of groins (about 12 km), is an area with clear predominance of erosion, with a maximum changes from 43 to 64 m in 34 years. Middle part of the spit is balanced consists erosion parts and accumulation. Eastern part of the spit is predominantly accumulation, with the maximum value of about 105 m in this period of time (Furmanczyk 1994).

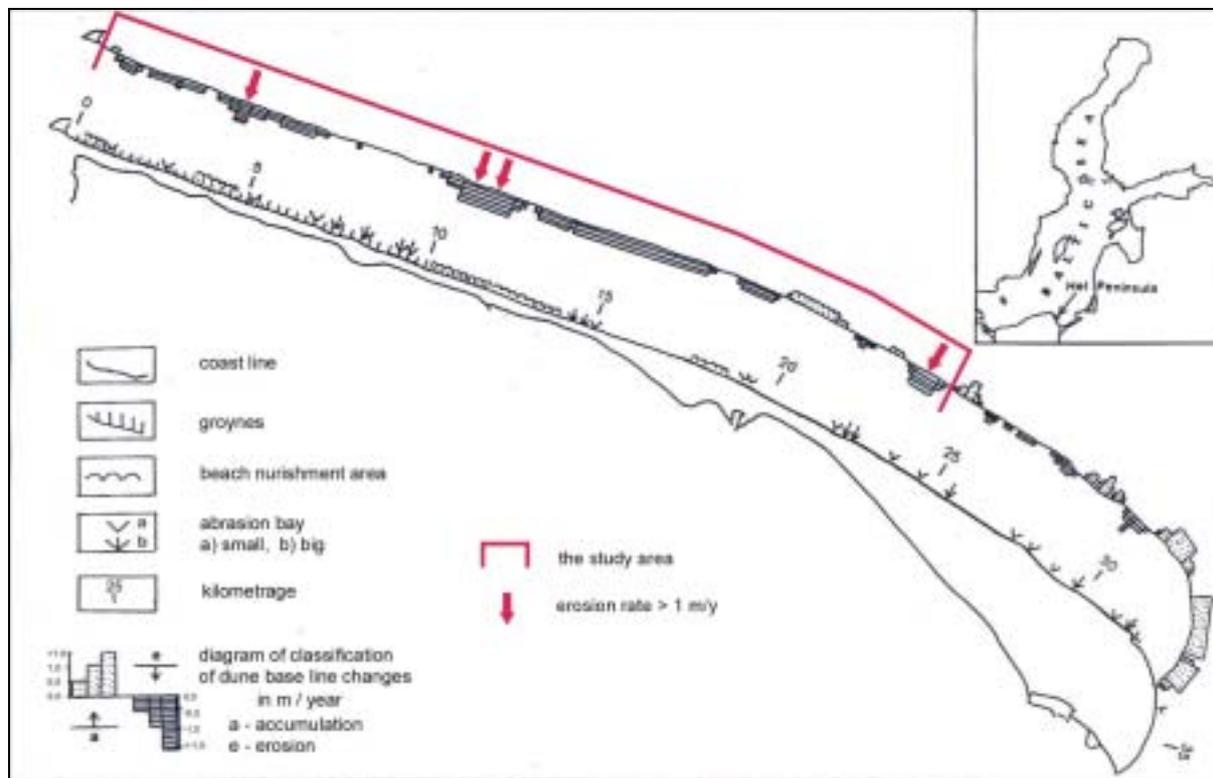


Fig.11: Classification of Hel Peninsula coast's changes in period of time 1957- 1991 years. (Furmanczyk 1994).

At the study area we can say that almost whole coast there is in erosion hazard but with various rate from 0 to >1 m/y. It was observed also that one year changes are comparable in value with 40 years changes. It means that the coastline is oscillating with relatively small rate of net movement (Furmanczyk 1994). It means that there is a big longshore transport of sediments depended from wind direction and his value is much higher that could be calculated from the rate of long term erosion value¹.

1.2 Socio – economic aspects

1.2.1 Population

The number of total resident population of the study area (urban communes Wladyslawowo, Jastarnia and Hel) is 23,771 (31.12.2000.). The total area of this communes amounts 6768 ha. The population density amounts 350 persons per sq km. There are 8 villages and towns on the area (from the West to the East): Jastrzebia Gora, Wladyslawowo (town), Chalupy, Kuznica, Jastarnia (town), Jurata, Bor i Hel (town) (Fig.12.). The biggest are town,

¹ Pilot area coast is very young in geological time scale. There are more and more facts that longshore transport of sediments on this area is much more complicated than was thought before. Sea level rising it is not enough clear reason of sandy coast erosion here. Very important problem need still solution it is human activity impact on natural coastal processes and coastal protection methods effectiveness in long period of time.

more than half of the total population lives in Wladyslawowo. The population in particular urban communes is shown in Table 2.

Table 2. Total population by sex (2000y.).

Commune	Males		Females		Total
	Count	%	Count	%	
Wladyslawowo	7 337	49,1 %	7 611	50,9 %	14 948
Jastarnia	1 977	48,2 %	2 124	51,8 %	4 101
Hel	2 346	49,7 %	2 376	50,3 %	4 722
Total	11 660	49,1 %	12 111	50,9 %	23 771



Fig. 12: Size of municipalities round the area of Hel Peninsula with reference to quantity of inhabitants.

Typical for the coastal non-urban areas domination of females doesn't occur in the study area. The main reason is proximity of the urban agglomeration Gdansk-Gdynia. Young women leave this area for education or work in cities. In the town Hel is naval base located with predominantly masculine stuff.

In the last time the population grew from 23.271 in 1996 to 23.771 in 2000. It is mainly because of immigration. Some of people working in seasonal tourist industry decide to stay for ever. The seasonal population (July and August) achieves 60.000, and the density 882 persons per sq km. The forecasted population trend shows the growth of adult and old

people group. The area is very attractive for summer houses and rich older people (potentially Polish Florida).

1.2.2 Economy

There are three sectors of economy important for the area: fishery and fishing industry (especially in Wladyslawowo and Hel), tourist industry (on all of the area), defense and military services (especially in Hel). Every town possesses suitable infrastructure for these economic functions. In Wladyslawowo there is a big fishing port, in Hel fishing, yacht and naval port and in Jastarnia fishing and yacht port. Jastarnia (especially the village Jurata) belongs to the most prestigious seaside resorts in Poland. The official summer residence of the President of the Republic of Poland in Jurata attract VIP's and other guests from the capital and foreigners. There is also Marine Laboratory of the University of Gdansk in Hel – an important and well known research center.

The number of jobs in the study area can be only estimated because of the lack of accurate statistical data (Table 2.). The official register of employment in Poland does not include firms employing less than 9 persons. Individual farmers and their employees are also not taken into account. The estimation presented in Table 3 is based on the register of firms (REGON) from 1998. The seasonal employment can vary depending on weather. The year 1998 was rather good for tourists and the seasonal employment was high.

The yearlong employment can be estimated on 4310. There are ca 5300 private small (employing one or two persons) businesses registered in the area as well. In the public services (mainly administration, education, health services) are employed ca 900 persons (7% of the seasonal and ca 20% of the yearlong employment). In Hel there are at least thousand jobs in military sector, but the accurate number is not available. In the tourist season (July, August) the estimated number of jobs grows to 12.300. Most of them are located in the commune Wladyslawowo. Due to high revenues from local taxes the urban communes Wladyslawowo, Jastarnia and Hel belong to the richest in the region and even whole country.

Table 3. Yearlong and seasonal employment (1998 y.).

Town	Industry and construction	Market services	Public services	Total yearlong employment	Total seasonal employment (estimated)
Hel	191	144	235*	592	1 100
Jastarnia	80	550	125	757	2 400
Wladyslawowo	1 503	846	547	2 961	8 800
Total	1 774	1 540	907	4 310	12 300

* without military - at least 1000 jobs.

Whole Hel Peninsula including interested area belong to the *Seaside Landscape Park*.

1.2.3 Land use

In the area of interest there is land use specific for sandy spit. Beside of built-up area surrounded by gardens, there are railway, state road, forests, meadows and wastelands. At



the area of technical belt the beaches and dunes, mostly afforested, exist. There are no arable fields on the area of interest.

On the narrow spit beside of technical belt, road and railway are situated merely few municipalities. Clean water, beaches and air as well as seaside dunes landscape caused enormous tourist popularity of this region. Unfavorable conditions for building outside the area of existing municipalities caused a lot of limitations in permanent residential buildings development. Buildings are placed in the wider parts of spit, over the flat ground behind the dunes.

1.2.4 Assessment of capital at risk

The most important problem of erosion is connected with three places:

- The beginning section of the spit, where there are no properties, but there is an infrastructure: road and railway, that are very important for communication along the spit. This infrastructure could be affected by erosion.
- The km No 4 the most narrow part of the spit. At this place the width of the spit is only 200 m. It is also a great erosion observed there. The infrastructure the road and the railway could be affected by erosion.
- Kuznice – small town protected by seawall covered by sand with a great erosion problem in surrounding. Practically whole town is affected by erosion hazard.

Much less problem of erosion is connected with two other places:

- At the beginning of the Jastarnia town, near cemetery and the church. It is observed a strong erosion there. In some section of the coast a natural dune is eroded almost completely and an artificial dune protect area and also seawall made by gabions. There is still 100 m from the railway. Properties are located behind the railway.
- Hotel "Bryza" in Jurata. The hotel, is located just on the dune too close to the beach. There is a gabion's seawall located there, and beach nourishment is done there very often. The property of Hotel "Bryza" there are in erosion hazard.

2. PROBLEM DESCRIPTION

Quite big longshore transport of sediments towards east supplying Hel Peninsula was existing in this area in the past. The source of sediments were eroded cliffs from the region between Jastrzebia Gora and Wladyslawowo. Problems were appearing always in the beginning part of Peninsula.

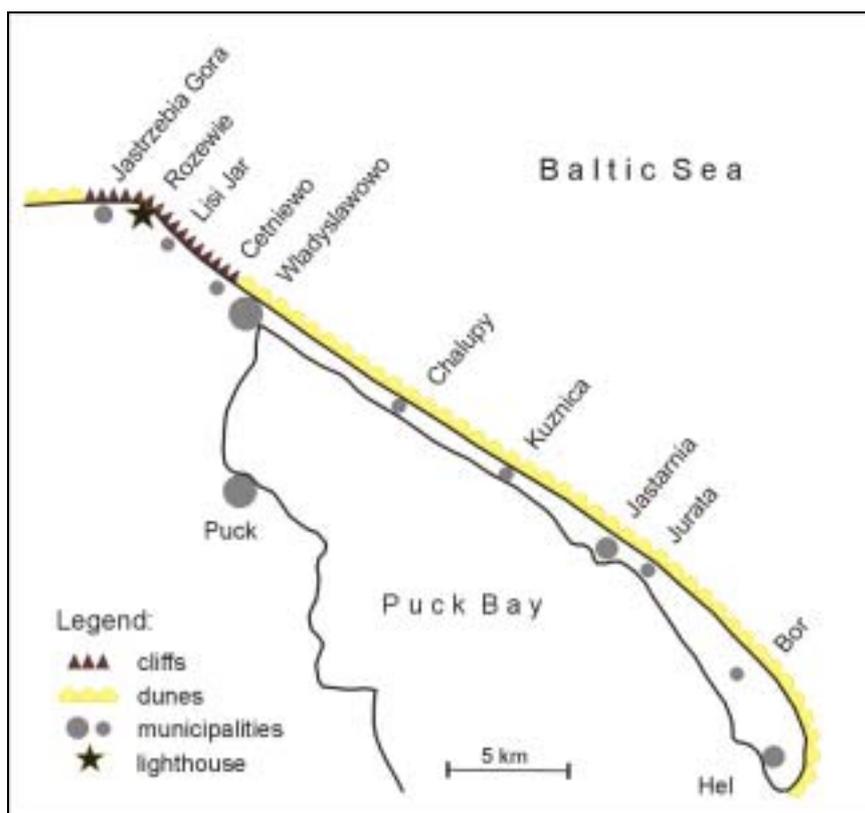


Fig.13: Hel Peninsula and basic coast types existing there.

In historical times there were difficulty with keeping the communication along the spit. It was very often, that the water was overflowing across the Peninsula, especially at the beginning of Peninsula. The Peninsula in the 17th century was also dug in many places and than was forming the archipelago with forts. Next at the end of 19th century there were existed positions of dune's supervisors, who were taking care over the dunes: creating (fences), supplementing (sand) and stabilisation (grass, trees).

In year 1905 the seawall for protecting the lighthouse in Rozewie was built. It caused that from the source of sediments were exclude the Jastrzebia Gora and Rozewie, so the supplying of Hel Peninsula was significantly decreased. In 1936 year the harbour in Wladyslawowo at the root of Hel Peninsula was funded. A supplying of Hel spit coast from longshore transport was broken since then. Since that time we can observe progressive erosion of spit coast especially at the beginning of the spit. Since 1948 to 1983 a system of groins was successively construct from the beginning of peninsula to the Kuznice town through 12 km of the coast. The problem is, that erosion of the coast never stops. The groins did not stop erosion in long-term of time. They stop erosion for a couple of year only.



At 1990 the process of beach nourishment was done successively. It was the last time, because at the most sections of the first 10 kilometers of the coast, the main dune system was eroded almost completely. To the 1994 was successively build an artificial dune to the high +4,5m above sea level along interested area. At present all places, where erosion appears, are supplying by beach nourishment successively.

Finally we can say, that erosion of the interested area of the Hel Peninsula is still existing, but is compensated by beach nourishment in the policy option: *"hold the line"*. The beach nourishment is an optimal option of the protection for the spit. This option is friendly for tourists, because the beach is still existing, that is extremely important for tourist resort – the most important source of income.

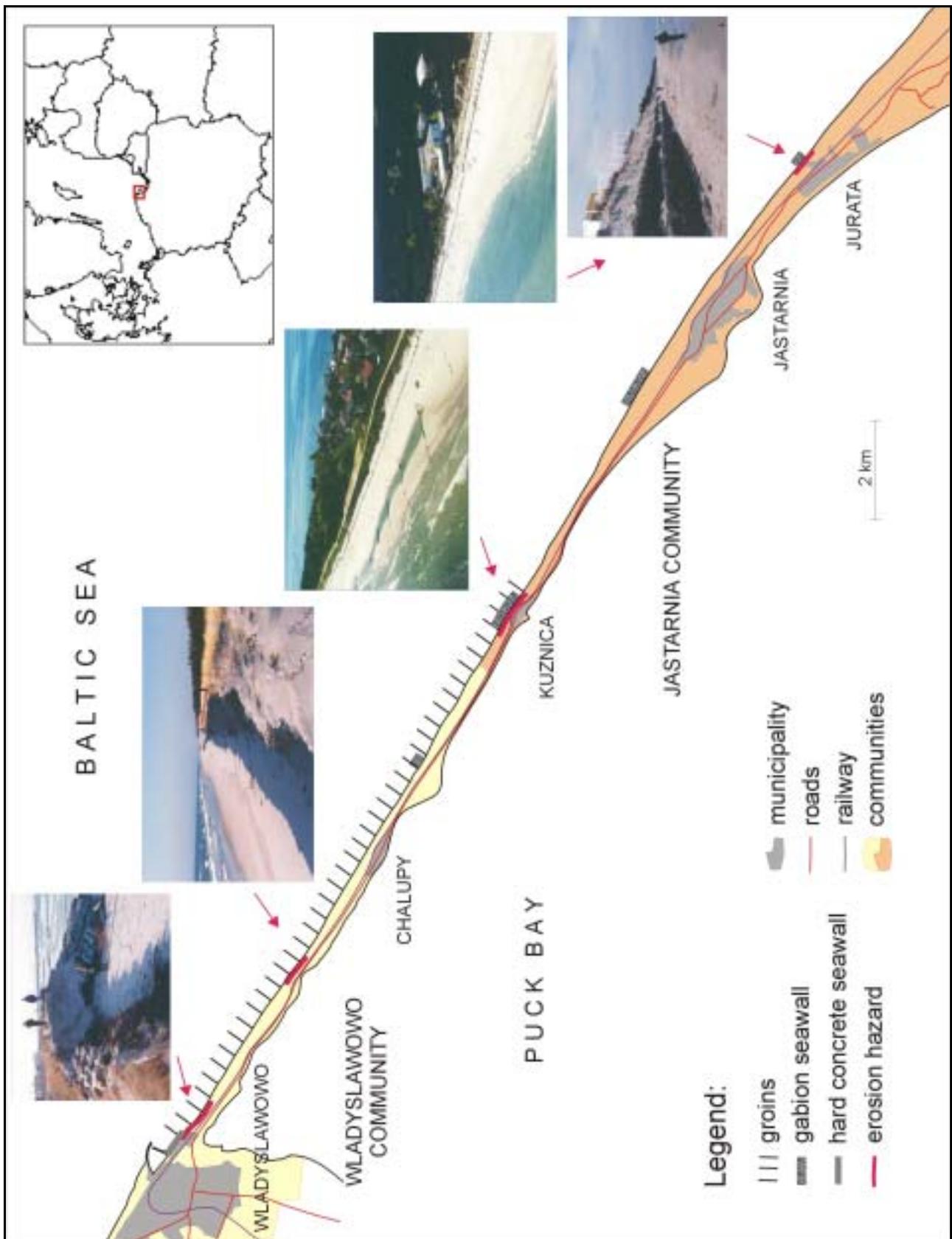


Fig. 14: Location of eroding sites on the Hel Peninsula (phot. by K.Furmanczyk).

3. SOLUTIONS/MEASURES

3.1 Policy options

More than a half of the spit is very narrow: less than 300 m (at the beginning less than 200 m). A communication along the spit by train and by cars are very important. A couple of small towns are located there also. In case the only one policy option was adopted: **HOLD THE LINE.**

3.2 Strategy

Since 1990 the only soft measures were adopted with very limited hard measures, where property are or could be in erosion hazard.

3.3 Technical measures

3.3.1 Historic measures

The first human activity on the Hel Peninsula was revegetations dunes and revegetations forestry as well as creating the bulkheads protecting the lower part of dunes. These activity took place in XIX century and were shown on the Gersdorf map from 1818 year (Piatkowski 1988).

Application of more effective coast protection method became need after building the Wladyslawowo Harbour (Fig. 15) in 1935 year. The first protecting works began in 1936 year building two light wooden seawalls filled with sticks in Chalupy and Jastarnia region. All these seawalls were destroyed by the sea completely. In 1937 year in the vicinity of Wladyslawowo Harbour the hard concrete seawall was built. It was 120 meters long, but next it was extend of 130 meters long bulkhead filled with concrete's blocks which was destroyed very quickly. In place of it new 300 meters of concrete seawall was built in 1952 year (Basinski 1963).

After II World War, because of strong erosion on the east side of Wladyslawowo Harbour the protecting works grown in strength:

- In years 1946-1948 44 single groins 100 m long in the distance of 90 m were built (the last 4 groins were in the distance of 180 m) – destroyed until 1996 year.
- In year 1948 on the section of 8 kilometers single groins 120 m long in the distance of 90 m were built – destroyed until 1996 year.
- In year 1949 bulkhead filled with concrete's blocks 860 m long was built – destroyed until 1996 year.

In the Kuznica region works protecting the coast included:

- In years 1950-1951 on the 430 m of the coast bulkhead filled with concrete's blocks was built (this construction was extending and repairing in years 1958, 1960, 1963 and 1970) – destroyed until 1996 year.
- In year 1963 17 groins between 11.96 and 12.32 km were built.

- In years 1983-1988 on the about 1.5 km of the coast embankment strengthened by concrete's rubble and concrete's sleepers.

In the region between Wladyslawowo and Kuznica works protecting the coast included:

- In year 1954 between 4.5 and 5.5 km of the Peninsula 16 groins and 180 m long seawall were built – destroyed until 1996 year.
- In year 1957 between 8.5 and 10.5 km of the Peninsula 23 groins and 160 m long seawall were built – destroyed until 1996 year.
- In years 1960-1961 between 5.5 and 7.5 km of the Peninsula 20 groins were built.
- In years 1969-1970 between 10.25 and 11.93 km of the Peninsula 31 groins were built.

Thus since 1948 to 1983 the hydrotechnical constructions included all area of 12 km from Wladyslawo to the Kuznica on the east. Continuous need of protection areas behind the hydrotechnical constructions results from the "link-side effect" and lack of material caused by cut off the longshore drift of sediments by building the Wladyslawowo Harbour.



Fig.15: Location of the Wladyslawowo Harbour, 1999 (photo by P.Domaradzki).

From the beginning of 80s the policy option of coast protection has been changed. Activity concentrated on renourishment instead of hard constructions building. List of activities carried out these days (since 1980 y.) is in Annex 1. Generally we can say that on the Hel Peninsula seawalls were built in the municipalities neighborhood. The area between municipalities were protected by groins only. Currently all coastal zone sections of Hel Peninsula is protected by nourishment of the beaches (Annex 1).

3.3.2 Type of measures

The protection's activity on the area of Hel Peninsula can be divided into two period of time:

- Hard measure until 1980 year
- Soft measure since 1980 year

Building hydrotechnical constructions (until 1980)

- Revegetation dunes and revegetation forestry; using as a first forms of coastal protection on the Hel Peninsula in 30s of XX century, currently revegetation is according with new approach to Peninsula protection, so is using commonly for dunes and areas behind its strengthen (Fig. 16).



Fig. 16: Revegetation of the artificial dune, Jastarnia region, 1992 (photo by K.Furmanczyk).

- Sticks fence: constructing at the dune base line position for dunes protection, exist on large area of Hel Peninsula.
- Wooden seawalls filled with sticks; archaic form of coast protection, not using at present.
- Single groins of different length and distances between each other – strong storms and continuous lack of the sand material in underwater part of the coastal zone made the groins didn't work properly; they even enlarge the erosion hazard (Fig.17).
- Bulkheads filled with concrete's blocks; popular form of protection using in early phase of Peninsula protection, all constructed bulkheads are destroyed, recently not using in this area.



Fig.17: Single groins and beach nourishment, Wladyslawowo region, 1999 (photo by P.Domaradzki).

- Embankment strengthened by concrete's rubble and concrete's sleepers or clay and rubble embankment strengthened by reinforced concrete's sleepers; not advanced technical form of protection having character of emergency protection (Fig. 18 and Fig. 19).



Fig. 18: Concrete's sleepers seawall, Kuznica region, 1992 (photo by K.Furmanczyk).



Fig. 19: Partly destroyed concrete's sleepers seawall, Kuznica region, 1995 (photo by K.Furmanczyk).

- Combined seawall (layers of sticks and reinforced concrete's sleepers) covered by sand; using as form of strengthen the dune (Fig.20 and Fig. 21).



Fig. 20: Structure of combined seawall visible after strong erosion of the protected dune, Władysławowo Harbour, 1995 (photo by K.Furmanczyk).



Fig. 21: "Link-side effect", strong erosion behind the seawall in Wladyslawowo; combined seawall is visible as well as sacks filled with sand used for emergency coast protection during the storm, 1995 (photo by K.Furmanczyk).

- Medium seawall (gabions lying over the stics and gabion basis); gabions are the wire baskets filled with stones of properly sizes according to wave parameters, they are lying over the different basis (stony, geotextil, sticks) and can be covered by sand (dune). Fig. 22 – Fig. 25.



Fig. 22: Eroded dune, opened and visible gabion seawall, Jurata, 1995 (photo by K.Furmanczyk).



Fig. 23: Seawall made with gabions lying over geotextil, Jurata, 1995 (photo by K.Furmanczyk)

- Medium seawall (gabions lying over the stony basis).



Fig. 24: Medium seawall, slope behind the seawall revegetated, region of 8 km, 1994 (photo by K.Furmanczyk).



Fig. 25: Gabions lying over the stony basis, seawall constructed in front of partly destroyed concrete's sleepers seawall, Kuznica, 1996 (photo by. K.Furmanczyk).

- Hard seawalls; constructing with concrete, using, when the erosion hazard is strong and the building are in direct danger (Fig. 26).



Fig. 26: Hard concrete seawall on the east from Wladyslawowo Harbour, 1991 (photo by K.Furmanczyk).

Beach nourishment (since 1980 till now)

In years 1980-1981 the materials were deposited under the water line on depth 3-5 m (**underwater nourishment**), but the results in form of remaining sand were only about 20%; since 1989 nourishment is caring out directly on the beach (**beach nourishment**);

this method of protection is currently the main method using for the Hel Peninsula; the costs are high, but results are best in comparison with other form of protection that we used there (Fig. 27 – Fig. 29).



Fig. 27: Shaping the dune slope after beach nourishment, Jastarnia region, 1991 (photo by K.Furmanczyk).



Fig. 28: Works over the renourishmed dune, pipeline is visible, Kuznica region, 1994 (photo by K.Furmanczyk).



Fig. 29: The new renourished dune, region of 15 km of the coast, 1994 (photo by K.Furmanczyk).



4. EFFECTS AND LESSONS LEARNT

4.1 Effects related to erosion

Erosion did not stop, but now an artificial beach and dune is eroded instead of natural dunes. But the sand must be supplied constantly in the eroded places.

4.2 Effects related to socio–economic aspects

The chosen strategy work. There are no negative changes observed in socio–economic aspects. The beach, the most important source of income is still existing, and the communication along the spit (railway and road) is existing too. The beach nourishment seems to be a tourist attraction in the season.

4.3 Relation with ICZM

ICZM in Poland is strongly centralized. Any decisions there are in Maritime Offices hands.

4.4 Conclusions

The policy option: hold the line and the strategy: soft measures were adopted. In the case of narrow sandy spit it works well. It is the one problem only – money. The nourishment need to be done at last every second year. In other case the coast will start to be eroded and the properties and infrastructure of the Hel Peninsula will be in erosion hazard.

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