

CHARZYKOWSKIE LAKE

5.4.1 HEAVY METALS AND PESTICIDES

FIRST REPORT

INFLUENCE OF STRESSORS OF CHARZYKOWSKIE LAKES

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INTRODUCTION

The objective of the pilot operations performed under the task 5.4 is to assess the anthropogenic impact on the Charzykowskie Lake. It was concluded that the influence is irregular and depends on the type and degree of the impact on the littoral zone, shape of the basin and water quality of tributaries.

Measurements will be carried out in 3 deepest waters and 10 transects in littoral zone that represent different lake areas and various degree of impacts on the littoral zone. Transects will undergo monitoring for biotic elements (benthos, macrophytes) and abiotic elements (bottom material, water). Particular attention will be devoted to bottom sediments that form as a result of local biological production, and the inflow of allochthonous substance from the atmosphere and basin. We have observed sedimentation, accumulation and liberation processes of substances from sediments.

Deposited sediments consist of elements that are conducive to eutrophication: i.e. nitrogen, phosphorus as well as harmful substances: pesticides and its metabolites as well as heavy metals. Sediments that line the basin have an important role in water exchange between the lake and groundwaters. Therefore, it is important to determine the insulating properties of the sediments.

The study of bottom sediments will consist of an analysis of sediments composition with particular focus on heavy metals and pesticides. The permeability degree of sediments will be assessed¹.

During the first stage of work we focused on selecting transects. In order to do so we made a DTM of the basin that visualised the shape of the bottom. It was made on the basis of an archival 60 year old material. We also were able to obtain data on distribution and characteristics of the Charzykowskie Lake sediments from that period. The digitised dimensional images will serve as a background for interpreting the analysis results carried out within the project. In addition, we started work on identifying stressors impacting the Charzykowskie Lake. We have gathered archival materials on land development, water and wastewater management of the municipality of Chojnice and characteristics of major tributaries of the Charzykowskie Lake.

Barbara Nowicka

¹ We started work on modifying the sampler's end-piece for assessing the hydraulic conductivity of sediments

1. NATURAL CONDITIONS

1.1. Lake characteristics

1.1.1. Location

Administratively, the Charzykowskie Lake is located within the Pomeranian Voivodeship in the municipality of Chojnice (Fig. 1.1). It constitutes homogeneous water body (code 20290) located in water region administered by the Regional Water Management in Gdansk. The lake is in use of fish farms of the Charzykowy Fish Farm Ltd. It represents an abiotic type 3a and has been classified as a European whitefish type. Furthermore, it performs recreation functions and is the cradle of Polish sailing.

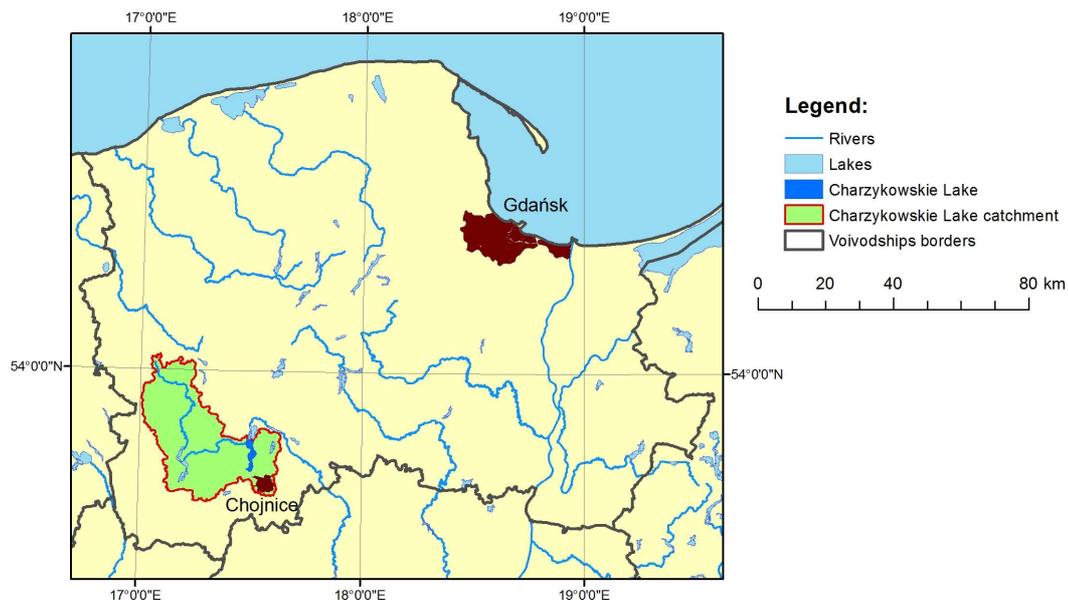


Fig 1.1. Location of the Charzykowskie Lake in the Pomeranian region

The Charzykowskie Lake is situated in the physico-geographical macroregion of the South Pomeranian Lakeland on the Charzykowska Plains (Kondracki, 2002). It is located within the Polish largest forest complex of the Tuchola Forest. Natural assets of the Charzykowskie Lake are the reason that the lake was designated as a Biosphere Reserve of the Tuchola Forest in 2010. In addition, the Lake is located within the protected area of the Zaborski Landscape Park. Since 1996, it lies in the buffer zone of the Tuchola Forest National Park. Further, the lake lies within the Special Area Protection for Birds „Wielki Sandr Brdy” (PLB220001; Natura 2000) and parts of the lake basin are situated in the Special Area of Conservation (Fig. 1.2).

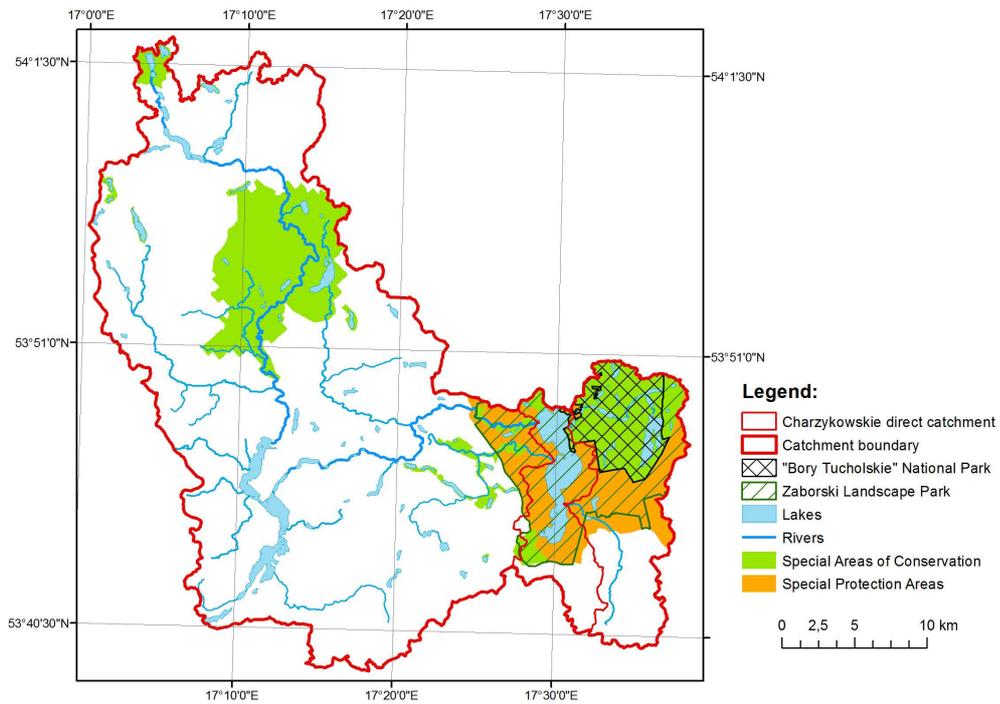
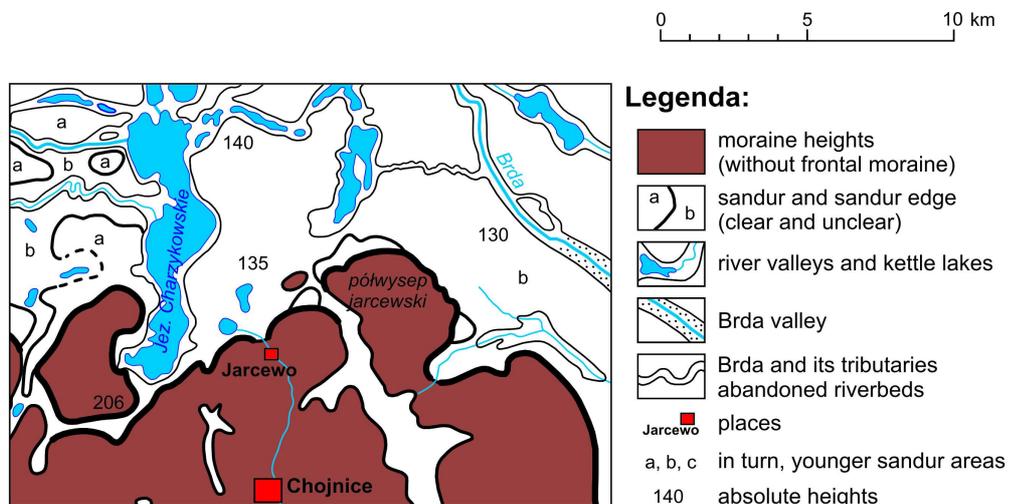


Fig 1.2. Location of the Charzykowskie Lake within the protected areas

The Charzykowskie Lake is located in the Brda catchment and is concerned as a flow tank. The Brda River is the main tributary; the remaining tributaries are Red Stream (Czerwona Struga), Jarcewska Stream (Jarcewska Struga), Seven Lakes Stream (Struga Siedmiu Jezior) and several smaller in the rich in water south. Its outflow of water from reservoirs is through Brda to the Karsinskie Lake (Długie Lake).

The lake is located on the border of two geomorphological and lithological forms. Push terminal moraines occur in the southwest. Its height is up to 80 m above the Charzykowskie Lake level. The clay that forms the moraines sinks in northerly and northeasterly direction and is covered with sandy outwash fan (Brda Sandur) Fig. 1.3.



According to Galon, 1953

Fig. 1.3. Location of the Charzykowskie Lake within geomorphological units

1.1.1. Origins

The lake fills the southern part of the glacial gutter (N – S). The Gutter is classified as the largest to be localised on the Polish lowlands. Its length is 17 km, width reaches up to 2,5 km and its depth is up to 50 m. In addition to the Charzykowskie Lake the following lakes fill the form: Długie, Karsinskie and Witoczn.

The gutter is the result of complex processes that took place since the Krajenska sub-phase of the last glaciation (16,8 thousand BP). According to Pasierbski (1973), during the oscillation of the ice sheet, the glacier lobe entered the older subglacial gutter and significantly increased the narrow form (glacial erosion). During deglaciation, the gutter was preserved by gutter blocks of dead-ice and was buried under the ground moraine deposits and fluvio-glacial sediments. According to Nowaczyk (1994), the melting of the dead-ice blocks and the beginning of the biogenic accumulation is dated 1540 BP. Sediments characteristic of moors were created at that time. Lake sediments accumulated in the gutter later on, which proved that the lake range was much greater than it is today. According to Tołpa (1950), the lakes found in the gutter used to be connected. As a result of lowering the water level and subsequent aeolian processes the Charzykowskie Lake was separated by a sandy peninsula from the remaining part. The lake marl located below the aeolian peninsula sediments should evince this. Today the Charzykowskie Lake is connected with Długie Lake by a narrow Brda channel. The original shape of gutter was transformed due to accumulation of river and Aeolian/biogenic processes. This resulted in several lake terraces, river scars, coastal embankments and constantly developing river deltas. (Dysarz, 2003).

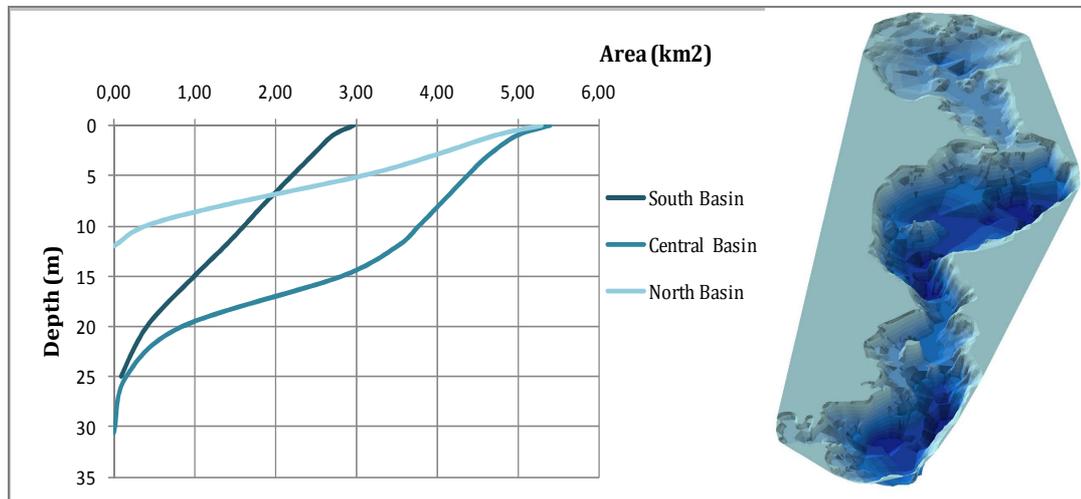
1.1.2. Formation of the lake basin

Official data provided by the Inland Fisheries Institute (IRS) based in Olsztyn illustrate the state as for 1948. The data was developed on the basis of the Stangenberg bathymetric plan made in 1:5000 scale which was based on 7000 measurement points (measurements were done from the lake ice cover). It slightly differs from the data publicised by the author of the study. In order to interpret the results we needed to take into account the contemporary changes of the lake shape that occur in the littoral zone. The changes are a result of land relief factors that have been occurring in the lake and its coastal areas for the past 60 years. This concerns particularly large rivers-mouths.

According to IRS, the surface of the water table is 1363,8 ha with volume of 134533,2 thousand m³. The maximum length of the reservoir is 10025 m, width of 2425m while the total length of the coastline is 31925 m. The maximum depth is 30,5 m. The average depth is 9,8 m and according to Thienemann it is classified as a transitional-mesotrophic lake. The largest lake bed is between 15.0 and 20.0 m isobath (18.8%). There is also a large lake bed between 5.0 and 8.0 m isobath (18.4%). According to Stangenberg (1950), the littoral surface calculated up to 6 m of depth, represents 35.6% of the lake total surface. The steep slopes of the lake basin do hamper the development of vegetation. According to IRS, in 1960 the emergent plants occupied 3.9% of the lake while 20.3% were submerged.

The lake basin is diversified, meaning that there are two islands (1.12ha and 2ha) and its shallow waters are overgrown with reed. Underwater thresholds separate the lake into 3 lake hollows: southern, central and northern. The following elements of the bottom shape are prominent in the southern basin: longshore bank with a steeply descending lake slope and the profundal zone with numerous hollows and water-mounts. The central basin has a relatively flat and deep bottom. The central basin is separated from the northern basin by a double threshold of 1 up to 3 m of depth;

and two reed islands that form a lake phytolittoral. The northern basin is significantly shallower than the rest. The shallow coastal zone changes smoothly into a benthic zone. This part remains under the influence of Brda.

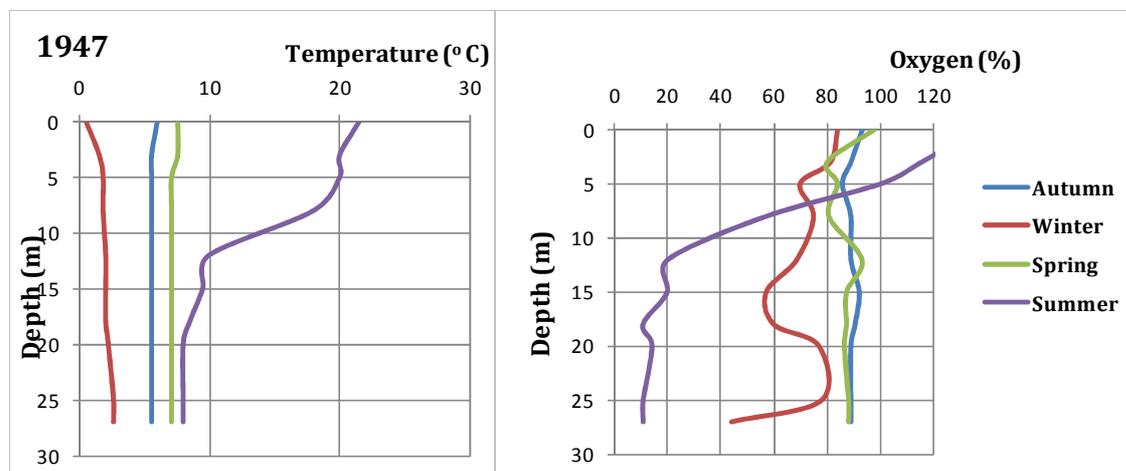


Developed on the basis of the Stangenberg's bathymetric plan, 1950

Fig. 1.4 Morphometric differentiation of the Charzykowskie Lake basin

1.1.3. Water mixing conditions

The relative depth of the Charzykowskie Lake (0,008) shows the shallowness of the lake in relation to its surface and makes water mixing into considerable depths very easy. This confirms the exposure index of value of 139. The studied lake belongs to a dymictic type. Water mixing into the lake bottom was documented during the period of spring and autumn homothermy (Fig.1.5). In summer, the thermal stratification is normal and maintains a relative isolation of deeper layers from external environment. Hypolimnion occurs at the depth of 12 m. The ratio of epilimnion to hypolimnion is 1:0.835 which indicates that there are favourable conditions for lake eutrophication.



Developed on the basis of the Stangenberg's bathymetric plan, 1950

Fig. 1.5 Stratification of water temperature and oxygen saturation in the Charzykowskie Lake in four seasons of 1947.

1.2. Catchment characteristics

1.2.1. Morphological structure

The shape of the Charzykowskie Lake catchment has been formed approximately 16 000 - 15 000 BP during the successive cycles of the Baltic glacier standstill and retreat (in the line of Pomeranian Phase and then further to the north). This conditioned the emergence of various glacial and fluvio-glacial forms. During the postglacial period the terrain shape was further transformed as a result of fluvial and denudation processes, i.e. melting of dead ice blocks and intense aeolian processes (Nowaczyk, 1994).

Terminal moraines were formed during the Pomeranian stadial in approx. 15 200 BP (they were located in the source section of the Brda River). The water of the melting glacier moved southwards and built an extensive outwash fan on the moraine clay [it was formed from fluvio-glacial sands, gravels and stones] (Galon, 1963). One of them is inclined towards the south of Sandr Brdy. It is located 180 m above sea level near the city of Miastko. Located from 145 to 133-135m above sea level in the Charzykowskie Lake area. It is divided by uncovered moraine islands and peninsulas. On southwest it borders with a series of accumulated terminal moraines with glaciectonic disorders (Charzykowsko-Gwieździnskie moraines). The maximum relative height ranges from 25 up to 30 m. The culmination – Mountain Wolność is at 206,1m above sea level and is elevated approximately 80m above the water surface of the Charzykowskie Lake. The sandur surface varies. The direct catchment of the Charzykowskie Lake consists of impressive dune forms with height reaching up to 14 m. In addition, there are numerous depressions of various origins (Liberacki, 1958). Sandur is crossed by multidirectional subglacial gutters. Gutters are usually of elongated shapes that sometimes extend to several kilometres. Width varies from 100 to 1800m. The course of gutters varies (they may cross or converge radially) although mostly they have southerly direction. Gutter bottoms are generally uneven with a number of hollows and thresholds. Deeper spots in gutters are filled with lakes. The most impressive one is the Charzykowskie Lake gutter.

Such shape of geomorphological structure determines the following characteristics of the water cycle (Nowicka, 2003):

- The main drainage system constitutes the set of deep subglacial and abrasion gutters;
- Varied shapes of gutter beds support retention processes. Most lakes and wetlands occur within gutters;
- The course of subglacial gutters, its slope and shape of beds form the cascade structure of the drainage system;
- Numerous hollows, often superstructured with a set of dunes indicate that endorheic areas constitute a significant share, and their hydrological role depends on their morphometric features and lithology;
- Steep slopes of subglacial gutters and deep subglacial hollows that often exceed 10%, create opportunities to form surface runoff and erosion processes;
- Sediments with a very good and good permeability predominate and support water infiltration processes;
- Varied lithology of deeper layers does limit the natural circulation of groundwaters.

Poor podzols have formed on the sandur sands. The southern plateau part of the catchment is covered by brown soils (moraine clay is its native bedrock. Peat soils and muck-peats occur only in the valleys of Brda, Red Stream and on the southern shore of the lake. In terms of agricultural suitability these areas are classified as poor grasslands.

1.2.2. Climate characteristics

Characteristics were developed on the basis of data gathered by the IMGW Chojnice Station.

The analysis shows that the mean average air temperature in the 1956-1980 was +7,1°C, the maximum average temperature was +10,7°C and the minimum average temperature was +3,4°C. The warmest month was July with +16,9 °C, and the coldest was January with - 2,6°C. Minimum air temperatures during the above mentioned period varied from -5,0 °C in January and up to 11,7 °C in July. On the other hand maximum temperatures varied from - 0,5 °C up to +22,2 °C.

The average precipitation sum of 1956-1980 was 577 mm. The lowest values of 25 mm occurred in February. July was the month with the largest amount of rainfall with 87 mm. Nearly half of the average precipitation sum occurred during four months, i.e. May, June, July and August. The average monthly sums indicate spatial variations in the total catchment area of the lake. Maximum values recorded in the northern part of the area are: 819 mm for Piaszczyzna, 688 mm for Leśna Huta and 686 mm for Miastko villages. The southern part that is located in the rain shadow of climax moraine hills receive lower precipitation - Chojnice 561mm. For 170 days with precipitation there are 50 snowy days. The first snow occurs mostly in October – November and the last in April (sometimes in May). However, in particular years some exceptions from this have been recorded.

Snow cover occurs on average on Nov. 26 (1961-1990, Bednorz 2001). The earliest snow developed on October 22 and the last on January 21. On average, the last snow cover remains disappear in the second half of March (20 Dec. at the earliest and not later than May 2). Therefore, the snow cover (since the first snowfall) may sustain even for 110-120 days. However, the average number of days with the snow cover is 65 days a year. The longest period of snow cover was 135 days in Chojnice and the shortest was 12 days (1961-1990). The average snow cover height was about 10 cm (1966-1995).

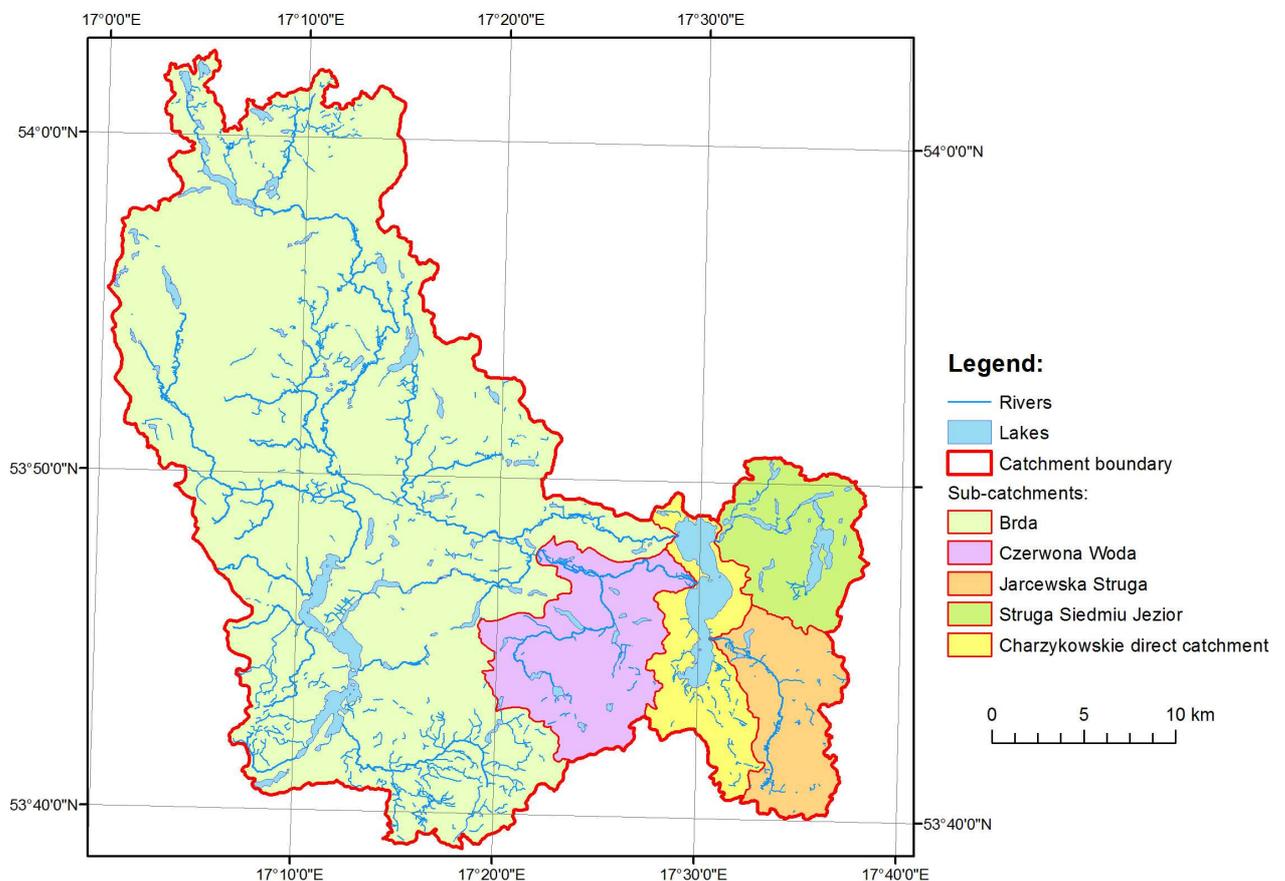
The studied area is dominated by winds of western sector, namely westerly and southwesterly winds (15-20% of all observations) plus northwesterly winds (10-15%). Its total frequency reaches 50-55% (during 1966-1995 and 1991-2000). The most common wind velocity is up to 5ms⁻¹, including the silence period this constitutes approx. 85% of all the cases (Climatological Atlas of Poland, 1971). The weakest winds blow from NW to E (< 3,5 ms⁻¹), while the strongest (> 4,5 ms⁻¹) from SW-W (tab. 1.1). During year, the share of silence is of a few %, with maximum occurrence at the turn of summer and spring, and minimum in February and November. It is worth noting that while the wind does not exceed 4 ms⁻¹ on average in any month, the wind does exceed the wind speed at certain times during a day. Wind maximum velocity occurs in the afternoon while the minimum at night.

Tab. 1.1 Wind direction frequency of total cases and the average wind speed (v) of each direction in Chojnice (1991–2000) [Szydel, 2002]

	N	NE	E	SE	S	SW	W	NW	C	Sum /average
%	6,9	7,5	8,1	10,7	11,4	19,7	18,2	13,2	4,3	100
v [ms ⁻¹]	3,4	3,4	3,3	3,7	3,6	4,8	4,6	3,4	0	3,8

1.2.3. Hydrographical structure

Brda River flows to a cascade of lakes. The first of the lakes is the Charzykowskie Lake. The river flows into the lake in the northwestern part of the reservoir (Northern Basin). Subsequently, less than 2 km away it flows into the next lake. Brda River is the largest tributary to the Charzykowskie Lake. It drains 70% of Charzykowskie Lake catchment (Fig. 1.6). Other major tributaries are Red Stream (Czerwona Struga), Seven Lakes Stream (Struga Siedmiu Jezior) and Jarcewska Stream (Jarcewska Struga). There are a number of small stream outlets in the south that discharge water from the seepage spring area. Fig 1.6 shows the division of the Charzykowskie Lake catchment.



According to Hydrographic division of Poland

Fig.1.6 Hydrographical division of the Charzykowskie Lake catchment

The Brda River stream origin is to the east of the Miastko village. To be precise it rises from the Smolowe Lake. The upper part of Brda has a quite considerable gradient of 0,13‰ and a well shaped valley with incision into the surrounding sandur ground. Brda passes through smaller lakes southwards and then it changes its course to the east. The river has an extensive system of right-banks tributaries. It can be classified as a poorly shaped river-lake system. Brda flows into the Charzykowskie Lake at 80,4 km. Its width varies from 15 to 30 m and the water levels are usually high. During 1960-2009, the average flow of the river was 6,2 m³/s, with minimum of 2,07m³/s and almost 7 times greater maximum of 14,2 m³/s (as recorded by Ciecholewy water-gauge). Brda regime was illustrated in Fig. 1.7. Since this route Brda changes to a typical river-lake system (meaning that the waters flow through 8 large ribbon lakes). The change in river gradient (0.05‰)

and a large quantity of deposited material caused that a vast delta was formed in the Brda mouth to the Charzykowskie Lake (delta develops constantly).

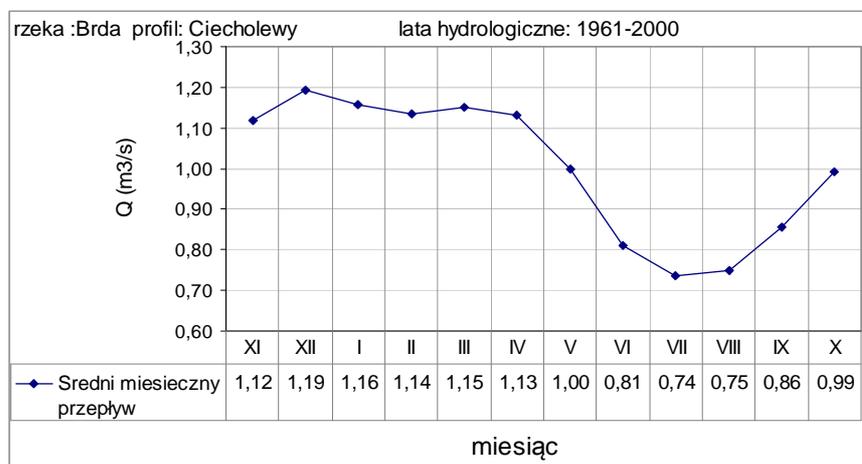


Fig.1.7 Monthly average flow of Brda in Ciecholewy profile (m^3/s) in hydrological years of 1961-2000

Red Stream - the left-bank tributary to the central lake basin of the analysed lake is a stream of 18,5km length. It originates at the altitude of 152m above sea level and is an outflow of the Klodzko Male Lake. The total catchment area is 78,8km². The catchment is build from sand, mineral-organic and organic deposits formed in the river valley. The river valley is narrow with an average gradient of approx. 1,7‰. The river creates a system of meanders. Water lifting is common in the lower part of the river due to beaver activities and dams. The river estuary section characterises approx. 4m of mouth width, average depth is approx. 0.2m and maximum is approx. 0.34 m. The river mouth is overgrown with high reed. The river isn't controlled hydrologically. Discharge measurements are performed sporadically. For instance, in the spring of 1995 the discharge was 0,183 m^3/s , while in the summer it was 0,548 m^3/s (Goszczyński, 1997). In summer 2002, water discharged through Red Stream channel with 0,38 m^3/s in the Kopernica profile (Nowicka, 2003). Water electrical conductivity was 343 $\mu\text{S}/\text{cm}$, pH 7,5 and total hardness indicated 2,15 mval/l (12°n).

Seven Lakes Stream is a right-bank tributary of the Charzykowskie Lake. It has a 13 km length and drainage area of 41km². Catchment area of the Seven Lakes Stream is formed from sands and river-glacial gravels of sandur plains. In the north there are concentrations of dunes and blowouts. Depressions are filled by Holocene deposits: sands and river gravels, loams, lacustrine chalk, peat earth, peatbogs of transitional bog and mires. The Stream creates a river-lake system which consists of 8 lakes connected by short fluvial segments (including such lakes as: Ostrowite, Zielone, Jeleń, Bełczak, Plesno, Skrzyńska and Mielnica). The last lake is shallow and heavily eutrophicated. The river flows into the northern basin of the Charzykowskie Lake (nearly opposite the Brda mouth). In the river mouth occur complicated hydraulic relations with the lake (Nowicka, 2003). There are no natural tributaries. The river flow is monitored by The Tuchola Forest National Park (PNBT) beneath the Plesno Lake. In 2000-2004 the average discharge was 0,270 m^3/s , max. 0647 m^3/s and min. 0,332 m^3/s .²

Jarcewska Stream is a small river with 11 km of length. The surface of its catchment is 52,3km². Moraine upland constitute the southern part of the catchment which is observable as a so called Jarcewski peninsula (fig. 1.3.). In its lower reach river drains sandur plain which is a part of Charzykowska Plain. It is formed by sands and gravels of varied thickness. The river originates at

² To compare with Red Stream, in 1995 river discharge oscillated from 0,064 to 0,124 m^3/s (Goszczyński, 1997)

an altitude of 150 m above sea level, it drains wetlands and flows through the Wegner Lake. The Jarcewska Stream is then supplied with water from the Niedzwiedź Lake tributary. It then flows into the central basin of the Charzykowskie Lake (nearby Funka). The width of the water table is over 3,25m, max. depth is approx. 0,22m and the average depth is 0,15m. The tributary network is poorly developed. There are mostly drainage ditches in the middle and lower reach.

There is no permanent hydrometric monitoring and measurements are made on the occasion of other activities. According to Goszczyński (1997), the flow in 1995-1996 changed from 0,105 in winter up to 0,583m³/s in summer. The measurement carried out on 16/08/2002 below the road bridge in Stary Młyn indicated a 0,988m³/s flow (Nowicka, 2003). In 2008-2009, there were made 8 series of measurements (Nadolna, 2010). The flow in the estuary profile varied from 0,167 m³/s (19.VI.2008) up to 0,565 m³/s (01.III.2008).

Table 1.2 Hydrographical classification of the Charzykowskie Lake basin

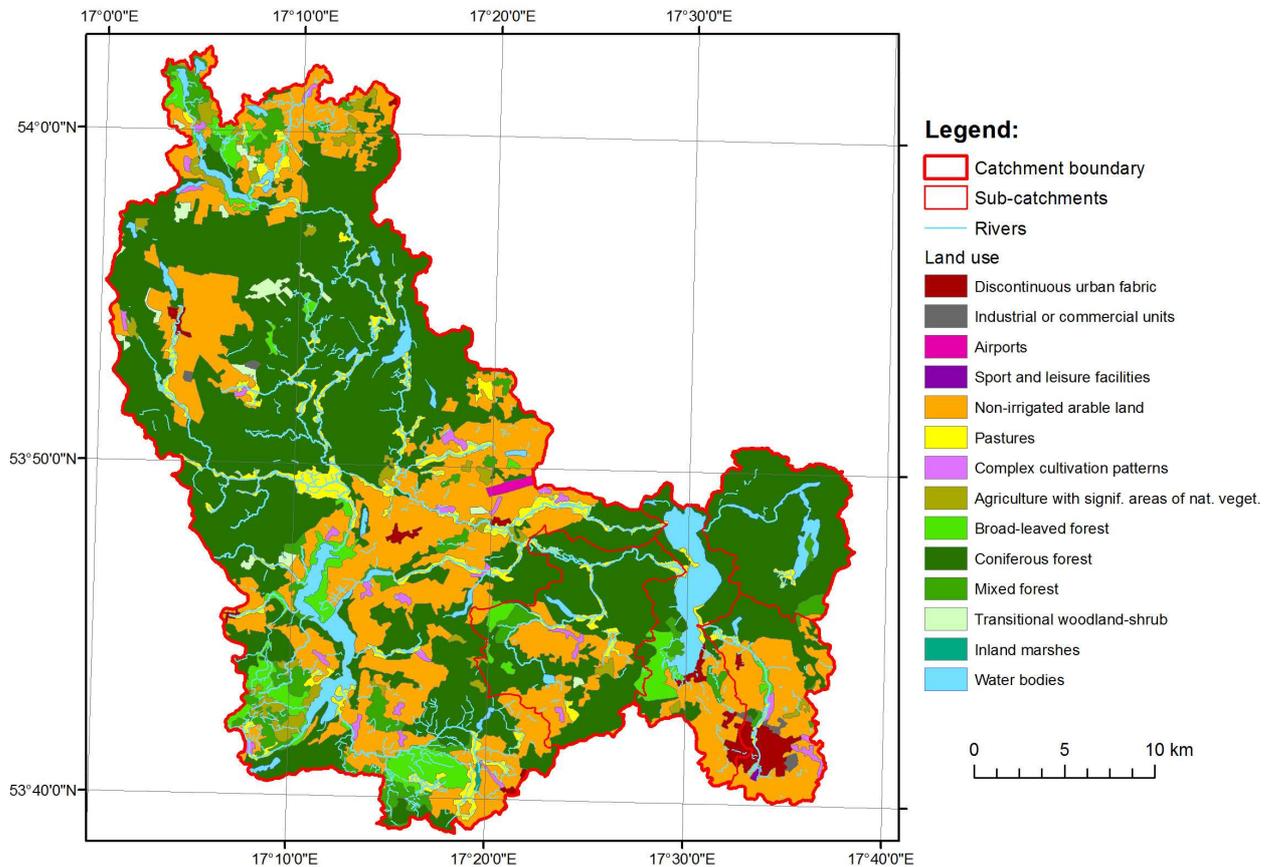
Name	Surface	
	km ²	%
Lake	13,49	1,50
Interior areas in the immediate catchment	22,00	2,40
Immediate catchment without flow	14,76	1,60
Immediate catchment (total)	36,76	4,0
Brda River	668,09	72,60
Red Stream	78,80	8,60
Seven Lakes Stream	41,00	4,50
Jarcewska Stream	52,30	5,70
Other/remaining	29,60	3,20
Catchment tributaries (total)	869,75	94,50
Total Catchment	920,00	100

Topographic map 1:25 000, PUW 1965

2. ANTHROPOGENIC IMPACT

2.1. Catchment land use

The total catchment area of the Charzykowskie Lake is wooded in 59% (Fig. 2.1) These are mostly National Forests with an implemented policy for harvesting timber. However, the north-eastern part of the catchment, the newly established Tuchola Forest National Park (1996) is under the legal protection. There are remnants of previous forestry departments and even-aged tree stands. Over 35% of the catchment is occupied by agricultural crops. Urban development constitutes minimal percentage but has an impact on the lake.



After: Corine Land Cover, 2006

Fig. 2.1 Land use structure of the Charzykowskie Lake catchment

Land use of particular tributaries catchments is very diversified, Fig. 2.2.

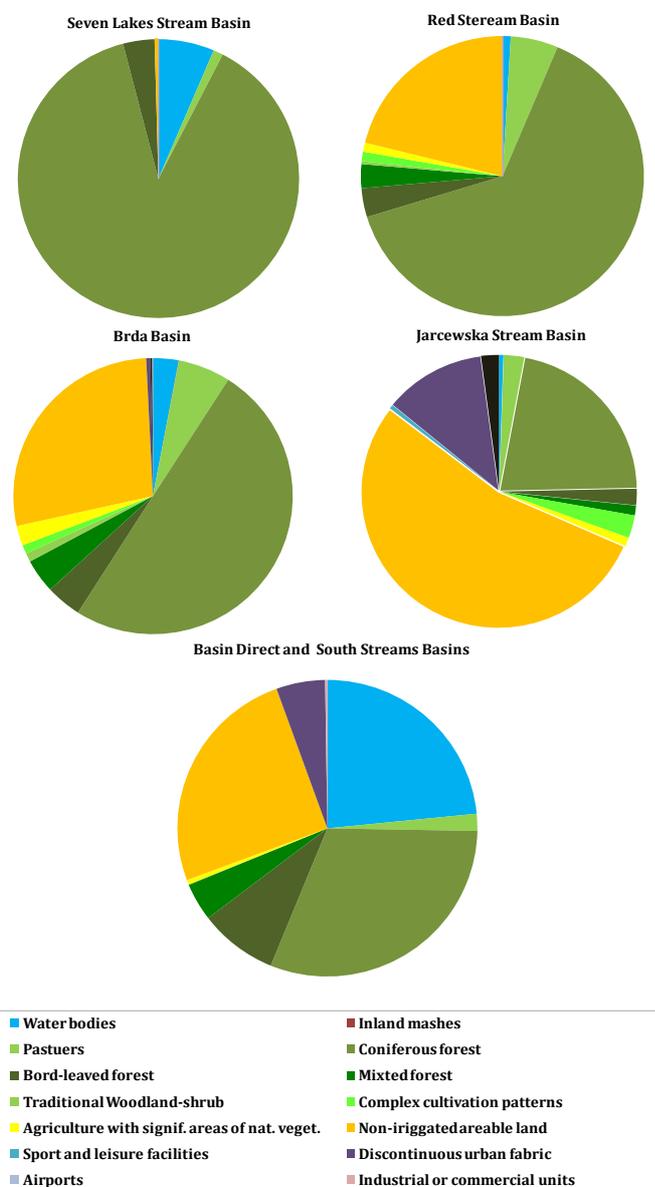
Seven Lakes Stream is a typical forest basin. Approximately 85% of the basin is located within the Tuchola Forest National Park. However, the southern and eastern fragments of basin are located in the National Forests area managed by the Brusy Forestry. 96 % of the basin is covered by forest and consists mainly of fresh and dry pine.

In case of the Red Stream the forests constitutes only 70% and occupies mainly the lower part of the basin. The Red Stream initially flows through the areas used for agriculture. Meadows, pastures, peat bogs and alders are common for the bottom river valley. The estuary section of the valley consists of arable lands and ecological areas which are accompanied by a dense network of drainage ditches. In addition, there is also a Kopernica village with multifamily settlements and backyard gardens. A holiday resort is located near the Charzykowskie Lake.

Brda basin has a similar structure. However, agricultural lands cover a greater area (at the expense of forests). Farming is also common in addition to the rural areas. According to Jutrowska (2007), there were 11 pig fattening farms in the Brda basin and one trout farm which may increase the number of living organisms.

Jarcewska Stream is an important tributary of the Charzykowskie Lake and contributes significantly to the state of the lake (it is the most urbanized basin). The Chojnice municipality has

approx. 40, 000 inhabitants and occupies 31% of the basin. Chojnice is known for its growing industry of food and electrical machinery. In addition, there are small villages and settlements present in the middle and upper basin area with about 450 inhabitants. By the Jarcewska Stream there are located Czartołomie and Jarcewo villages. There is also an expanding Chojniczki village and Stary Młyn settlement with backyard gardens near the river mouth. The river valley is crossed by a dense network of drainage ditches and is accompanied by grasslands. Grasslands are also present near the Niedzwiedź Lake. The southern shore of the Niedzwiedź Lake is used by the residents as a watering place, which is nearby a park with special camping area. Forest constitutes less than 25% and is common in the northern part of the basin.



After: Corine Land Cover, 2006

Fig. 2.2. Land use structure of the Charzykowskie Lake catchment divided into subcatchments as of 2006

2.2. Direct catchment management

The structure of the land use is presented in Fig.3.2. Forest constitutes more than 72%. The greater parts of trees are artificially planted with temperate coniferous forest associated with podsolc soils of Brda sandur. Beech forest with poor ground flora was preserved fragmentarily on the moraine deposits in the southeast (*Luzulo pilosae-Fagetum*) followed by acidophilous beech-oak Pomeranian forest (*Fago-Quercetum petraeae*). Due to the greater fertility of soils there was implemented a forest clearance in order to transform them into arable lands, that now constitute 21% of the direct catchment. So far we managed to avoid site development and forest clearance on the western shore. Furthermore, Lipińska B., (2003) argues, that the region is of landscape-nature importance. Urban areas constitute a small percentage and are orientated around 4 towns: Charzykowy, Funka, Bachorze and Małe Swornygacie. However, urban areas will grow inevitably.

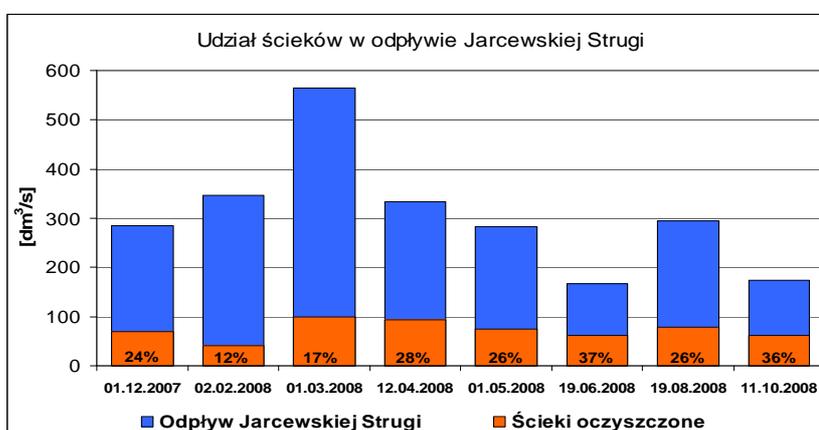
According to D. Król and R. Pernak (2003), the first documented mention of settlements near the Charzykowskie Lake date back to the Iron Age (650-200 years BC). Terrain nearby the lake and forest complexes supported development of fishing, hunting and gathering. The settlements were localized on the islands and peninsulas of the Charzykowskie Lake which enhanced their defensive capabilities. Two defensive strongholds (Charzykowy) were formed in the southern peninsula of the Charzykowskie Lake in the XIII century. Open settlements were located on the islands. At that time on the northern shore of Charzykowskie Lake, there was a hunting place of Pomerania Princes (Małe Swornegacie). It was located on animals migration track located on a narrow isthmus that separates Charzykowskie Lake from two lakes located below Charzykowskie. In the XVI century, the population was engaged in bee-keeping and tar manufacturing which was linked with forest clearance. At that time the mill, fishing and forest settlements have intensified. The mill and fishing settlements of Charzykowy moved to southern part of the lake. In the XVII century a mill settlement was established on the western lake shore in Funka (they introduced sawmill and grain mill). The high prices of trees favored tree felling in the XIX century. Timber was transported by water (by Brda river-lake system, including the Charzykowskie Lake). During that time, a fishing settlement called Stiportz was located in the northern shore of the lake and consisted of 151 inhabitants (Małe Swornegacie).

The adverse changes in forest management were reduced at the end of XIX century. Forestry and forest village were established at the mouth of the Jarcewska Stream on the eastern shore (Funka-Stary Młyn). During the early XX century, the Charzykowskie Lake started performing recreation functions (the 1st sailing club in Poland organized regattas there). The Charzykowy, Funka, Bachorze and Małe Swornygacie started performing a holiday resort function. Resorts were established on the southern and eastern shore. The rapid urbanization of the Charzykowy began in the XXI century and started performing a commuter town function of the Chojnice powiat.

Tourism is oriented in the vicinity of Charzykowy. Resorts and recreation (hotels, guest houses) and housings stretch from the southern edge of the lake, nearly up to Funka (Stary Młyn). Recreation facilities and individual resorts are located nearby Funka, Bachorze and Małe Swornegacie. Camping area is located on the east shore nearby the Seven Lakes Stream mouth. The main reason for recreation facilities established in the east was good accessibility (the road leads from Charzykowy to Małe Swornegacie and goes along the eastern lake shore). The western shore of the Charzykowskie Lake is used to a lesser extent. Small clusters of buildings (scattered farms) are common in Kopernica and Wolność settlements.

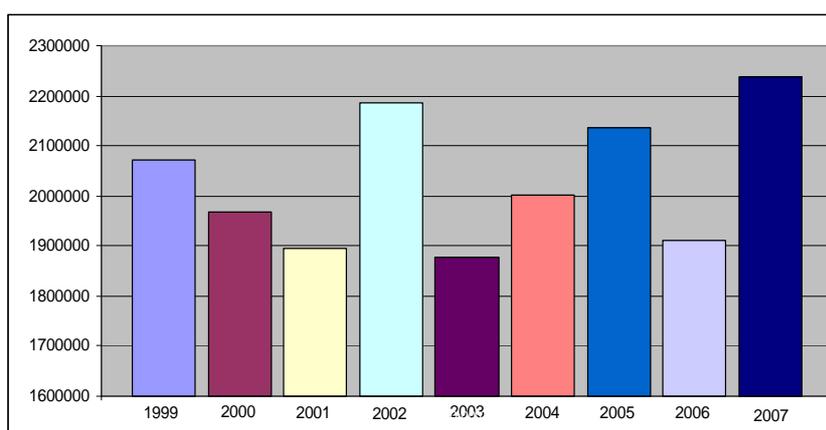
2.3. Sewage management

Villages located in the direct basin of the Charzykowskie Lake perform a role of holiday resorts during summer. Most of the objects are canalized and the sewage is discharged to Chojnice or Swornegacie sewage treatment plants. Some of the buildings in the township of Bachorze use septic tanks that are then transported to the local sewage treatment plants. The lake does not currently have any direct sources of water pollution. Until 2003, the waste from the Charzykowy sewage treatment plant were discharged directly into the lake. Until the sewerage network was introduced the sewage from Chojnice was of 347 m³ a day. However, the number doubled to 744 m³ a day in the mid-90s (Goszczyński, Jutrowska, 1997). Lake still remains a sewage receiver, which are discharged into the lake tributaries. Sewage is discharged through the Jarcewska Stream. Sewage originates from the mechanical and biological sewage treatment plan with reduced biogenic compounds Fig.2.3 and 2.4.



According to Nadolna, 2010

Fig. 2.3. Purified wastewater percentage in the Jarcewska Stream outflow (in the river mouth profile in different measurement periods, 2008)



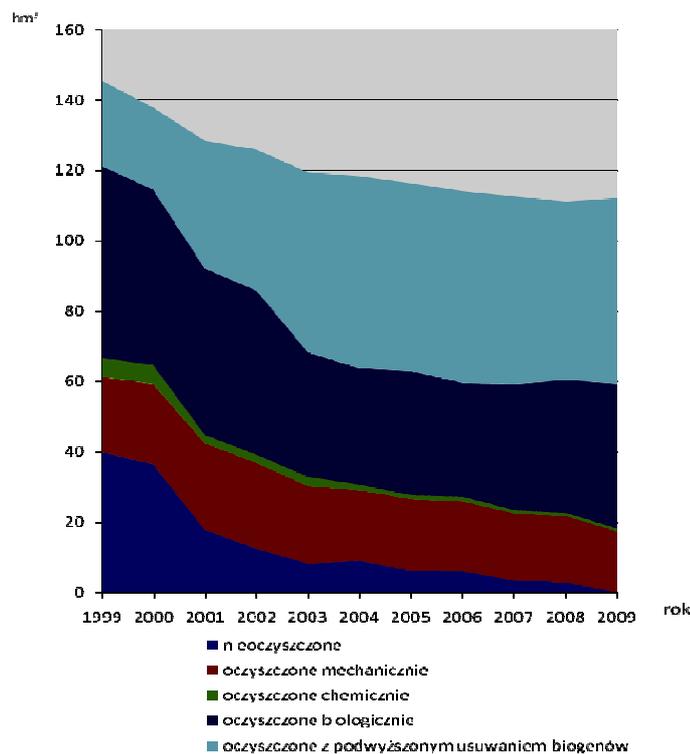
According to data provided by Chojnice Municipal sewage treatment plant

Fig.2.4 Amount of purified waste given in m³ (Chojnice sewage treatment plant)

A potential threat to the water quality of the Charzykowskie Lake may be also the Brda River pollutants. The surface of the total catchment occupies a significant area within which there are situated: Przechlewo commune sewage treatment plant, rural sewage treatment plants in Pietrzykowo, Koczała i Konarzyny Tab.2.1. Sewage originates from the above mentioned villages.

However, sewage comes also from smaller settlements which until recently preferred using septic tanks.

Regularities occurring throughout the country may be observed in the amount of generated waste in the discussed area. For economic reasons, there was implemented more economical use of water, both in households and industries. This resulted in a decrease in generated waste. Fig. 2.5. illustrates a trend of sewage amount change in Kujavian-Pomeranian region.



After: WIOŚ Bydgoszcz

Fig 2.5. Sewage amount trend change in the Kujavian-Pomeranian region

2.4. Breeding farms

Another considerable potential threat to the purity of the Charzykowskie Lake surface waters are industrial pig fattening farms located in the southwestern part of the total catchment - Tab.2.2. According to the data provided by the Environmental Protection Inspectorate (IOS), the total number of animals was estimated at about 60 000 until mid-90s. Breeding was conducted in concentrated manner and the animal excreta (manure and liquid manure) were used for agricultural purposes. According to the water-legal policy (that was in force back then), approx. 2 900 ha (4,33%) of the Brda River up to Ciecholewy water gauge was used for that purpose (Jutrowska, 2007). It was localized in areas of poor exploitable aquifer isolation. Sewage spraying was conducted in river valleys of Ruda and Modra and in the Brda valley (in case of the farm in Płaszczycyca). River valleys and glacial gutters constitute favorable conditions for sewage migration into aquifers. Hydrogeological maps show that all breeding farms are located in the direction of regional groundwater outflow, that provides water supply to the Brda River. In addition to the threat of using farm sewage in agriculture, it was also noted during monitoring that the lagoons accumulating sewage do leak.

At present, breeding facilities consist of total 105 000 animals. There was a fundamental change in animal excreta management. At present it is utilized by biogas plants located in Pawłówek, Płaszczycza, Kujanki, Koczała (as at late 2010). Fermented waste from biogas plants together with liquid manure are used on fields of 2 600 ha in total. In comparison to the previous periods, such utilization of excreta is significantly better for the environment. Basic information on the breeding farms is given in tab. 2.2.

2.5. Water quality of the Charzykowskie Lake tributaries

The monitoring of major rivers flowing into the Charzykowskie Lake started in 1975. Brda (Ciecholewy profile) and mouths of the Red and Jarcewska Streams were included in the study.

Brda is the main river that supplies pollutants generated by farms and facilities in the upper basin. Measurement profile is located above the Park's borders in the Ciecholewy village. Long term observations of Brda (Jutrowska 1996), indicate constant decline tendency of phosphate concentrations and stabilized level of ammonia nitrogen in water (as of 1985). Nevertheless, the Brda River provides about 65% of its load to the Charzykowskie Lake. In 2001 (for the most part of the year), Brda water supply in this profile was classified as I and II class (in physicochemical terms). The III class in this profile occurred in summer and characterised of oxygen deficiency. The sanitary condition of the river was also unsatisfactory as 41% of the samples were classified as III class and only 42% were classified as II class. However, the composition of organisms indicated good water quality (class II) and low concentrations of chlorophyll indicated even I class (Tab. 2.3) (Report WIOŚ, 2002).

Tab. 2.3 Quality assessment of waters flowing into the Charzykowskie Lake

River-profile	Year	Classification		Class	Decisive indicators
		physico-chemical	sanitary		
Brda - Ciecholewy	1999	III	III	III	E. Coli index, N-NO ₃ , dissolved O ₂ deficit
Brda - Ciecholewy	2001	III	III	III	E. Coli index, dissolved O ₂ deficit
Red Stream - Kopernica	1997	outside the class	outside the class	outside the class	E. Coli index, chlorophyll a
Seven Lakes Stream - estuary	1997	outside the class	II	outside the class	chlorophyll a
Jarcewska Struga - estuary	1994	outside the class	outside the class	outside the class	E. Coli index, chlorophyll a, BOD ₅ , TP, P-PO ₄ , N-NO ₃ , K,

(According to Report WIOŚ of 1998, 1999, 2000, 2002)

Jarcewska Stream is also an important tributary as it supplies amounts of phosphorus (it receives sewage from Chojnice). In the 80s, while draining 5,7% of the Charzykowskie Lake catchment it supplied it with 72,3% of total phosphorus. In the early 90s, the Chojnice sewage treatment plant improved the quality parameters of the Jarcewska Stream and significantly reduced phosphorus supply to 21,6% of the total phosphates load (Goszczyński, Jutrowska, 1997) - Tab.2.3 and 2.4. The water quality of the Jarcewska Stream deteriorates in the outflow of the Wegner Lake, in which its waters are being enriched with phosphorus released from the bottom sediments (Jutrowska, Goszczyński 1998)

The Red Stream is a tributary that flows into the Charzykowskie Lake and supplies water classified as II class in terms of biogenic compounds concentrations (though undergraded due to bacterial contamination).

2.6. Biogenic compounds balance

The balance sheet of the biogenic compounds constitutes fundamental information for accessing the sources of its supply into the lake. Therefore, it allows determining the load amount of lake area. The practical significance is that it allows developing adequate protective programs. The balance sheet of biogenic compounds was developed for the Charzykowskie Lake according to the methodology adopted in 2010, so that conditions and restrictions for lake/reservoirs/catchments usage could be specified (unpublicized materials). In the above mentioned study, the data used for calculating the direct basin use derives from the *Corine Land Cover Project, 2006*.

According to the study, the main source of the biogenic compounds in the direct catchment of the Charzykowskie Lake is the sewage discharge from point sources (more than 50%) and precipitation (34% of N and 28% of P). The factual load of the biogenic compounds is lower than the acceptance capacity. This ensures a sustainable trophic state in the lake. The total phosphorus load is much higher than the factual load which means that the phosphorus cycle is influenced by internal supply from bottom sediments.

Annual nitrogen and phosphorus load in the catchment (depending on its usage) is shown in the tab. 2.5.

Tab. 2.5 Annual nitrogen and phosphorus loads generated in the basin (kg/year)

Immediate runoff						
Development	Surface [ha]	N	P	% surface	% N	% P
Arable lands and scattered buildings	308,97	2780,73	92,69	11,9	5,4	5,4
Forest	2084,77	3127,2	208,48	80,5	6,0	12,3
Meadows and pastures	196,38	589,15	39,28	7,6	1,1	2,3
Precipitation	1346,66	17371,97	471,33	-	33,6	27,7
Point sources of pollutants						
Sewage treatment in Igly village		27 867,2	888,5	-	53,9	52,3
Sum [kg/year]		51 736,21	1 700,28	100	100	100

Tab. 2.6 External lake load of nitrogen and phosphorus (g/m²year)

Load	P	N
Spatial sources	0,060	1,77
Point sources	0,066	2,07
Sum [g/m ² *year]	0,126	3,84

This also covers precipitation and point sources of pollutants (Ld) and critical load (Lkr) in relation to the estimated value (on the balance sheet basis) allows surpass evaluation.

Tab. 2.7. Critical load surpass ($\text{g}/\text{m}^2\cdot\text{r}$)

External lake load of nitrogen and phosphorus				
	Permissible load	Critical load	Balance	Critical load surpass [%]
Phosphorus	0,294	0,589	0,126	-
Nitrogen	4,42	8,83	3,84	-

One drawback of the methodology adopted for balance sheet preparation, is the lack of estimates of biogenic compounds supply from the total catchment. It should be also noted that the biogenic compound amount that reach the reservoirs is very variable in time. The most important key factor influencing the process (among natural conditions) is the quantity and time distribution of precipitation. It results in very high diversity of size of phosphorus and nitrogen compounds load in particular years. According to Giercuskiewicz-Bajtlik (1990), the supply of these substances during humid years may be even up to 3000% greater than during dry years. According to measurements from 1995, the main supply of phosphorus to the Charzykowskie Lake is the total catchment (Goszczyński, Jutrowska, 1997). However, an important issue concerning the trophic level is the final amount of biogenic compounds accumulated in the water reservoir. Therefore, in this case we have to take into account the Brda River which is a significant outflow of the biogenic compounds from the lake. As a result, from the total amount of phosphorus supplied to the lake only about 7% remains in the circulation. In case of nitrogen it was a significantly greater value, because almost $\frac{1}{4}$ of the total nitrogen supplied to the lake was deposited. Given the above values and its permissible and critical values (as adopted in the study) it would seem that none of the values were surpassed. Therefore, we can regard this fact as another element that is responsible for stabilization of the trophic level of the lake.

The chemical elements are deposited mainly in bottom sediments. This process increases the total amount of sedimentary nitrogen and phosphorus. In favourable conditions e.g. as a result of bottom sediments resuspension or a change of physicochemical conditions in water/sediments contact zone, a great amount of N and P can be released in short time to ecosystem trophogenic zones and be included to biological circulation. From this point of view, the deposition of trophic elements in sediments is a negative phenomena and constitutes a so-called "ecological bomb" that may harm the ecosystem.

3. TROPHIC STATE, THE CHARZYKOWSKIE LAKE WATER QUALITY

3.1. Changes in trophic state according to Carlson index (TSI)

Water Law Act (Journal of Laws of 2005, No. 239, item 2019, as amended) defines the eutrophication as "biogenic compounds enrichment, especially compounds of nitrogen or phosphorus that cause accelerated growth of algae and other plant-life forms and leads to undesirable biological interference in the aquatic environment and deterioration of the water quality". The regulation issued by the Minister of Environment of 23.12.2002 on the criteria for nitrogen compounds originating from agricultural sources (Journal of Laws, No. 241, item 2093), sets limits for basic eutrophication rates (including: total phosphorus, total nitrogen, nitrate nitrogen, chlorophyll a, water transparency) for various water categories (standing waters, running waters, internal waters, marine coastal waters). The limits are recommended for assessing the phenomena.

The Water Framework Directive (RDW; 60/2000/EC) does not provide a definition for eutrophication. However, assessment of eutrophication degree is included in ecological state assessment. It is because an increased biogenic compounds supply and its concentration increase in water, affects the state of biological and physicochemical elements. In addition, the specific reference to the eutrophication requires assessment of each and every significant source of pollutants, including substances that contribute to eutrophication (in particular nitrates and phosphates) (Annex II 1.4, Annex VIII).

The Nitrate Directive definition (91/676/EEG) contains an identical description of eutrophication effects as the Water Law. However, they ought to be caused by nitrogen compounds supply and not by biogens in general. The purpose of the assessment of the eutrophication level is to identify „polluted waters” and to mark the catchments as vulnerable zones. Zones vulnerable to nitrates determined in the Nitrates Directive become protected areas in the Water Law records (RDW). Although, the Nitrogen Directive does not provide the criteria and the methodology to assess the phenomenon.

In order to meet the Nitrate Directive and Sewage Directive, the method for assessing eutrophication has undergone a significant evolution since the directives came into force. As mentioned, none of the directives provide methodologies for assessing the phenomena. In early 90s, EU countries in order to determine “polluted waters” or “waters at risk of pollution” used the OECD (1982) approach (in most cases). According to that method the eutrophication process may be described by determining basic parameters such as concentration of total phosphorus, chlorophyll a and transparency of water measured by Secchi disk. Some countries have expanded the list for concentration of total nitrogen and parameters that describe a well-known symptoms of eutrophication, such as changes in variety and abundance of living organisms, oxygen deficits, algal blooms or fish death.

A widely used indicator of trophic status is the Trophic State Index (TSI) developed by Carlson (1977). The theoretical basis for the index was the assumption that the trophic state depends linearly on the quantity of algae present in particular reservoirs. This can be assessed by measuring “chlorophyll a” concentrations, the Secchi disc transparency and the total phosphorus concentrations. The index ranges from 0 to 100, while values below 40 indicate oligotrophy and values above 70 indicate hypertrophy.

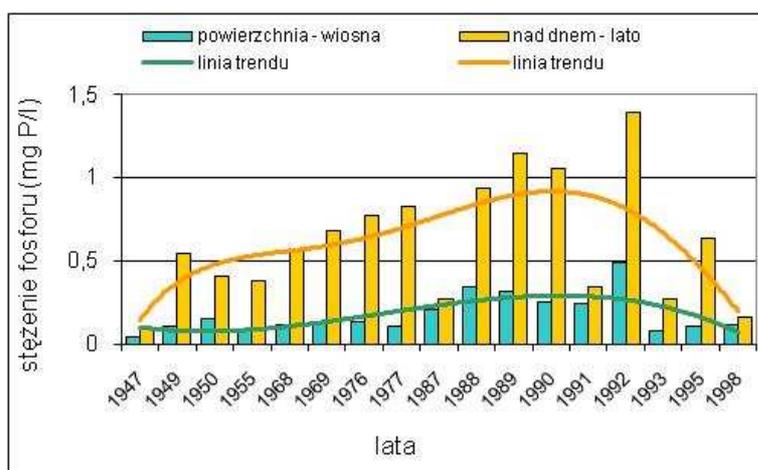
The average TSI value in the Charzykowskie Lake presented above indicates mesotrophic conditions. Over the quarter-century there were no fundamental changes. However, the values of total phosphorus differ and stand out in total evaluation. The reasons behind the variations may have a connection with the processes occurring in the depths of the water. Therefore, we need to assume that the conditions prevailing in the lake reflect the **eutrophic conditions** -Tab.3.1.

Tab. 3.1. Changes in trophic state of the Charzykowskie Lake according to TSI

Indicator	1982	1989	1995	2003	2009
Transparency	54,5	60,7	49,3	51,1	54,6
	eutrophy	eutrophy	mesotrophy	eutrophy	eutrophy
Chlorophyll „a”	57,8	61,6	56,2	62,3	59,6
	eutrophy	eutrophy	eutrophy	eutrophy	eutrophy
Total phosphorus	21,4	9,3	28,9	33,7	25,6
	oligotrophy	oligotrophy	oligotrophy	oligotrophy	oligotrophy
Average	44,5	43,8	44,8	49,0	46,6
	mesotrophy	mesotrophy	mesotrophy	mesotrophy	mesotrophy

According to: WIOS Bydgoszcz, Gdansk

The risk of accelerated eutrophication should be taken into account. The changes in the Charzykowskie Lake fertility in 1947-1998 (Fig. 3.1) may be an example. At the same time the trend of changes indicates possible cause of the phenomenon - the phosphorus load (in the sewage from Chojnice) supplying the Charzykowskie Lake, that has been changing in time.



According to Nowicka, Wiśniewski (2003)

Fig. 3.1 Long term change of phosphorus concentrations (TP) in surface and near-bottom water layers of the Charzykowskie Lake

Tab. 3.2 Physicochemical characteristics and water purity assessment of the Charzykowskie Lake

Indicator	Period and place of sampling	1982 r. ^{a/} ; spring (V), summer (VIII)		1993/94 r. ^{b/} ; summer (VII), spring (IV)		1995 r. ^{c/} ; spring (III), summer (VII)		1998 r. ^{d/} ; spring, summer (VI)	
		Value	Class	Value	Class	Value	Class	Value	Class
Average % oxygen saturation of hypolimnion	summer	10,3	III			0,7	non class	40,1	I
Dichromate COD method (mgO ₂ /l)	summer, 1 m below the surface	13,3	I			18,0	I		
BOD ₅ (mgO ₂ /l)	summer, 1 m below the surface	5,8	III	4,39	III	2,5	II		
	summer, sediment layer			3,25	II	2,5	II		
Phosphates (mg P/l)	spring, 1 m below the surface	0,271	non class	0,078	III	0,086	non class	0,12	non class
	summer, sediment layer			0,275	non class	0,573	non class	0,163	non class
Total phosphorus (mg P/l)	summer, sediment layer					0,632	outside the class		
	average value from spring and summer, 1 m below the surface	0,405	non class			0,106	III		
Mineral nitrogen (mg N/l) (NH ₄ -N + NO ₃ -N)	spring, 1 m below the surface	0,45	III	0,031	I	0,860	non class	0,47	III

Ammonium nitrogen (mg N/l)	summer, sediment layer			0,002	I	0,93	II	0,630	II
Total nitrogen (mg N/l)	average value from spring and summer, 1 m below the surface	0,78	I	1,905	III	0,82	I		
Electrolytic conductivity (µS/cm)	spring, 1 m below the surface	278	II	366	non class	312	III	395	non class
Chlorophyll a (µg/l)	average value from spring and summer, 1 m below the surface	12,0	II	39,9	non class	16,9	III	7,37	I
Seston dry mass (mg/l)	average value from spring and summer, 1 m below the surface	4,9	II			5,3	II	1,56	I
Secchi disk visibility (m)	average value from spring and summer	1,5	III	2,45	II	2,1	II	3,75	II
E. Coli index (excrement)	In spring and summer below the surface and above the bottom (the worst value)	1	I			0,4-4,0	II		
Field biological observations	whole year, complete lake								
Score result and total water purity class		2,55	III	2,70	III	2,73	III	2,44	II

According to: ^{a/} Cydzik i in. 1988; ^{b/} Cieścinski i in. 1996; ^{c/} Goszczyński 1997; ^{d/} Gwoździński i in. 1998)

4. BOTTOM SEDIMENTS

Lacustrine sediments form as a result of sedimentation of allochthonous matter – sands, mud, gravel and autochthonous compounds precipitated from water – silicon dioxide, hydroxides of iron, manganese, alumina, calcium carbonate, plant and animal remains, as well as degradation products of organic matter. Under natural conditions, the chemical composition of bottom sediments depends mostly on the properties of rocks that occur in the catchment area. In addition, climate conditions have an impact on the erosion processes, migration of the chemical elements and overall conditions prevailing in the lake that influence the physical, chemical and biological phenomena that occur in the lake.

The usage of the catchment does also influence the concentration of the potentially harmful elements (such as heavy metals and persistent organic pollutants). The catchment development and human activity affects to a great extent the distribution of the trace elements in the aquatic environment. Most of the potentially harmful elements and persistent organic pollutants (brought to the environment and surface waters either naturally or anthropologically) are retained in sediments. For this reason, lakes that were subjected to sewage characterize in very high contents of metals and toxic organic substances.

The increase of harmful substances content in contemporary lake sediments is associated not only with sewage disposal but also with surface run-off from urban and rural areas. The sediments composition in rural areas may be influenced by surface run-off from cultivated fields, orchards, forest plantations and animal farms. The increased pollutants content in contemporary sediments may be also caused by atmospheric deposition of lead, arsenic, cadmium, mercury and organochlorine compounds. Pollution of nowadays sediments (as observed in many places) is one

of the major environmental problems because of their harmful effects on biological resources and often indirectly on human health. The polluted sediments do mostly consist of higher levels of chemical elements that are or will be used in today's farms/facilities (meaning: mercury, cadmium, silver, arsenic, chromium, copper, nickel, lead and zinc). We also observe increased contents of organic pollutants such as polycyclic aromatic hydrocarbons (PAHs) and xenobiotics – organochlorine pesticides and polychlorinated biphenyls (PCBs)

The phase composition of sediments does also influence the trace element contents and persistent organic pollutants. These are mainly calcium carbonate, phosphate, organic matter, hydrated iron oxides and clay mineral content that play an important role in withholding the pollutants in sediments as a result of sorption and coprecipitation.

Geochemical study of Polish lake and river sediments is carried out by Polish Geological Institute (PIG) as ordered by the Inspection for Environmental Protection (GIOS). The study's aim is to control the content of heavy metals and harmful organic pollutants (PAHs) and monitor their change in time.

4.1. Criteria for sediment pollution assessment

In Poland, the regulation of 16 April 2002 issued by the Minister of Environment, provides criterion for sediment pollution assessment in terms of heavy metals and harmful organic compounds (PAHs) - (Journal of Laws, No. 55, item 498). However, the geochemical and criteria developed by Bojanowska (1998) are used for sediment monitoring as well as ecotoxicological criteria. Therefore, on the basis of geochemical criteria the classification of lake and river sediments is as follows:

Tab.4.1 Classification of sediment pollution

Indicator (mg/kg)	Geochemical background	Unpolluted sediments	Moderately polluted	Polluted sediments
Silver	<0,5	1,0	2,0	5,0
Arsenic	<5	10	30	70
Bar	52	100	500	1000
Cadmium	<0,5	1,0	3,5	6
Cobalt	3	10	20	50
Chromium	6	50	100	400
Copper	7	40	100	300
Mercury	<0,05	0,2	0,5	1,0
Lead	15	30	100	200
Nickel	6	16	40	50
Zinc	73	200	500	1000

While making a geochemical assessment a commonly used rule was assumed. The rule states that for anomalous element content in environment, a concentration higher than the average sum of content of this element and two standard deviations defined for studied population, is assumed. During the sediment pollution assessment (meaning tests of unpolluted sediments, moderately

polluted sediments and polluted sediments) for the polluted concentrations there were adopted two to five times higher concentrations than the geochemical background.

Depending on biogeochemical properties of particular chemical elements (mobility in the environment and toxicity to the biosphere) there were adopted 10-20 times higher concentrations than the geochemical background for the moderately polluted sediments, and 20-100 times higher for the polluted sediments.

The ecotoxicological criteria are based on two thresholds. *Threshold Effect Level (TEL)* – the content of chemical compound or element above which there may be observed toxic effects on organisms and *Probable Effects Level (PEL)* – the content of chemical compound or element above which there are often observed toxic effects on organisms.

These criteria were used in a few countries to determine the allowable concentration of pollutants in sediments. The threshold for harmful trace elements, polycyclic aromatic hydrocarbons, polychlorinated biphenyls and organochlorine pesticides were determined as follows:

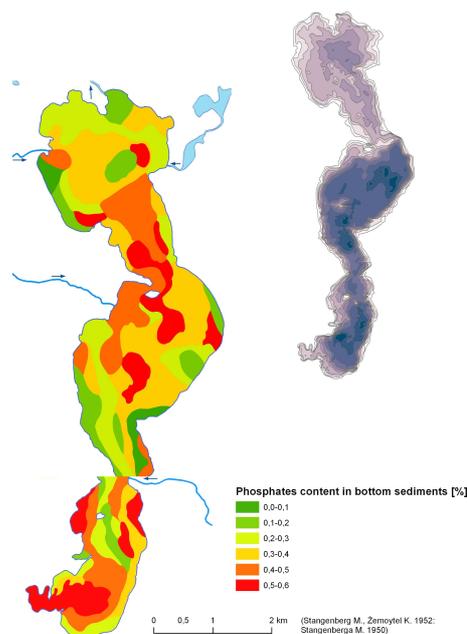
Tab. 4.2. Threshold values for harmful substances that damage the aquatic organisms in bottom sediments

Component	TEL	PEL
Elements (mg/kg)		
Arsenic	6	17
Kadmium	0,6	3,5
Chromium	37	90
Copper	36	197
Nickel	16	42
Lead	35	91
Mercury	0,17	0,487
Zinc	123	315
Polycyclic aromatic hydrocarbons (mg/kg)		
Acenaphthene	0,007	0,089
Acenaphthelene	0,006	0,128
Anthracene	0,047	0,245
Fluorene	0,021	0,144
Phenanthrene	0,087	0,544
Fluoranthene	0,113	1,494
Benzo(a)anthracene	0,032	0,385
Chrysene	0,057	0,862
Pyrene	0,053	0,875
Benzo(a)pyrene	0,032	0,782
Dibenz(a,h) anthracene	0,006	0,135
Sum _{11 PAHs}	0,461	5,683
Polychlorinated biphenyls (mg/kg)		
PCBs	0,022	0,189

Organochlorine pesticides (ppb)		
γ -BHC (lindane)	0,94	1,38
Chlordane	4,5	8,87
DDD	3,54	8,51
DDE	1,42	6,75
DDT	1,19	4,77
Dieldrin	2,85	6,67
Endrin	2,67	62,4
Heptachlor epoxide	0,6	2,74

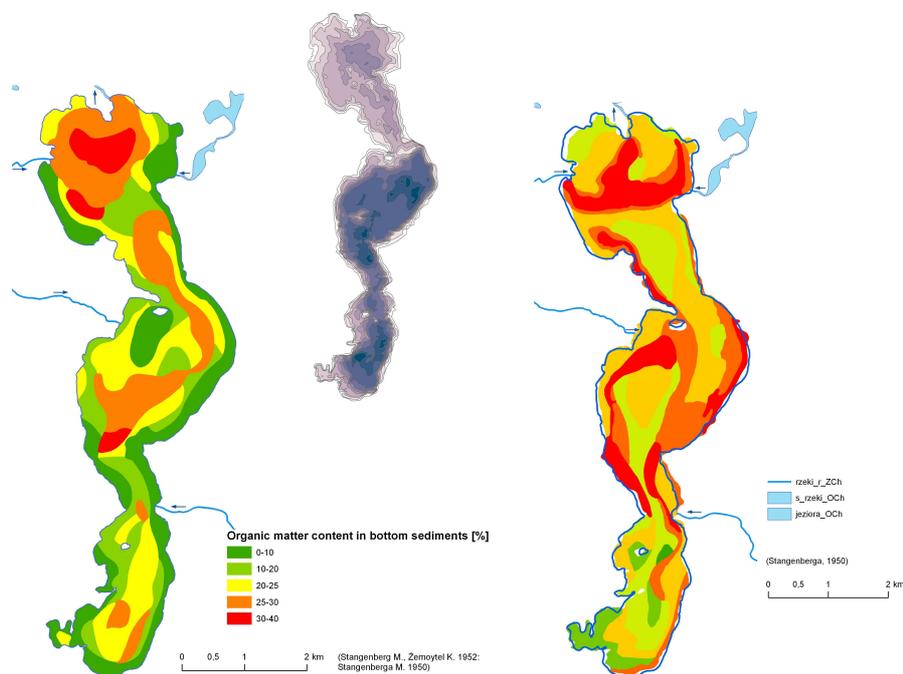
4.2. Archival studies of the Charzykowskie Lake sediments

The first study of the Charzykowskie Lake sediments was carried out by Stangenberg and Žemoytel in 1945. Based on 102 samples collected in winter from different parts of the basin, they determined spatial distribution of the sediment composition (CaCO_3 , organic and insoluble parts) and they established the content of iron and phosphorus. There are two types of sediments in the lake (mixed and silicate). According to the study, the sediments are spatially diverse. The coastal sediments have a coarse-grained structure with predominance of quartz sand and gravel. There are also present CaCO_3 derived from the mussel shells *Dreissenia polymorpha* and *Anodonta*. At the same time, there is a low amount of organic compounds. This concerns mostly the eastern coast which is exposed to winds. Organic compounds predominate in the middle of the gutter and at the southwestern bay. There is observed a variation of sediment composition in different basins. This is shown in fig. 4.1. -5.



According to Stangenberg and Žemoytel

Fig.4.1. Phosphorus spatial distribution in the Charzykowskie Lake sediments (in winter, 1945)



A)

According to Stangenberg and Žemoytel

B)

Fig 4.2. Organic matter content (A) and insoluble elements (B) in the Charzykowskie Lake (winter, 1945)

The study of the Charzykowskie Lake sediments conducted by WIOS in Bydgoszcz, Poland (Purity of the Charzykowskie Lake, 1997), has confirmed the spatial and seasonal differentiation of phosphate and iron content. The highest concentrations of phosphates were recorded in spring. Concentrations dropped in summer. These phenomena are associated with oxygen deficits during summer stratification of the lake. In case of chromium, there was observed an opposite phenomenon. Attention was drawn to the increased occurrence of manganese near the mouth of the Seven Lakes Stream.

The study of the Charzykowskie Lake sediments carried out by Polish Geological Institute in 2003 at maximum depression showed the following concentrations:

Tab. 4.3. Concentrations of chemical elements present in the Charzykowskie Lake sediment (in deepest place) in 2003

Chemical element	Unit	Value
Silver	mg/kg	0,5
Arsenic	mg/kg	5
Bar	mg/kg	123
Calcium	%	9,48
Cadmium	mg/kg	1,3
Cobalt	mg/kg	4
Chromium	mg/kg	20
Copper	mg/kg	12
Iron	%	3,19

Mercury	mg/kg	0,113
Magnesium	%	0,24
Manganese	mg/kg	2496
Nickel	mg/kg	9
Phosphorus	%	0,227
Lead	mg/kg	37
Sulphur	%	0,701
Strontium	mg/kg	97
Coal	%	12,3
Vanadium	mg/kg	16
Zinc	mg/kg	107

Source: GIOŚ website

In relation to the classification requirements these deposits were classified as follows:

- Unpolluted (according to regulation issued by the Minister of Environment)
- Moderately polluted according to geochemical criterion
- Occasionally harmful, affecting the living organisms (ectotoxicological criterion)

4.3. Selection of bottom sediment research transects

On the basis of the gathered material we initially selected 10 research transects Fig.4.3.

Most of the transects are localized on the east coast with is characteristic of the greatest anthropogenic impact (ports, road with heavy traffic) - Fig.4.4. We also took into account estuaries zones where spatially varied ectons are created. Those ectons are habitats for specific and diversivied flora and fauna.

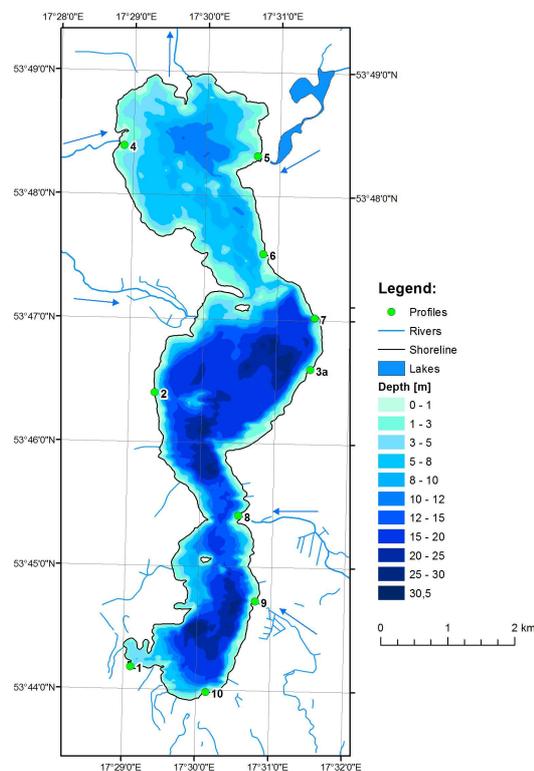


Fig. 4.3 Selected research transects of the Charzykowskie Lake

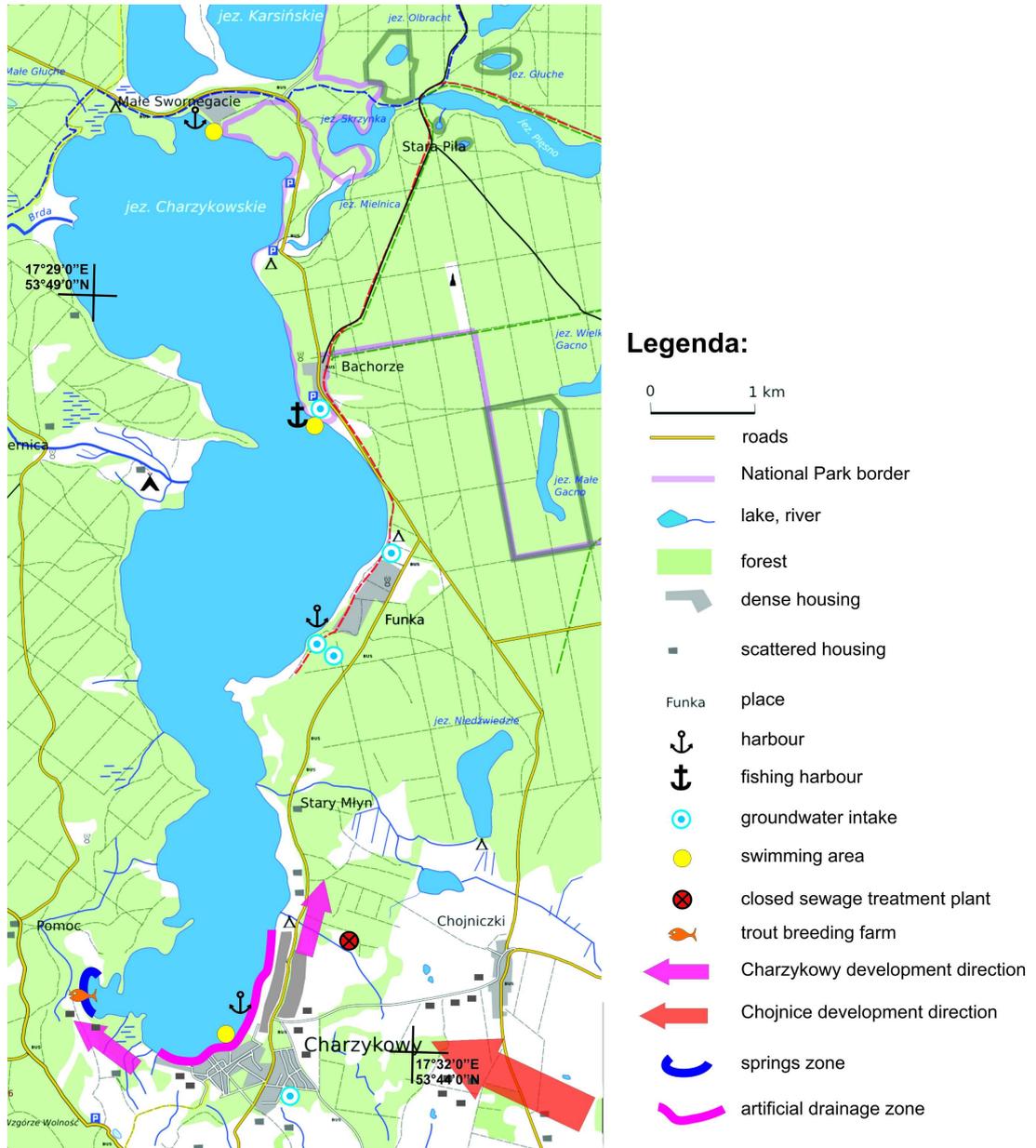


Fig. 4.4 Charzykowskie Lake shorezone management

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