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Influence of Morphology Changes on Flow and Water Exchange in the Odra Estuary

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Abstract

Knowledge of the hydrodynamic conditions and the exchange of water in estuaries is important for ecological, navigational and water management reasons. The morphology, river flow, sea level and local winds constitute important factors that influence the water currents and rate and extent of the mixing of salt and fresh water. The influence of the morphology changes on flow conditions, on the penetration of salt into the estuary and on the water exchange in the estuaries in this paper are analysed on the example of the Odra Estuary. The morphology of the Odra Estuary, and specially the Świna Strait, has changed immensely since the beginning of the XVIII century. The analyses were performed on the basis of data from in situ measurements and results of calculations. For the calculation the three-dimensional model ESTURO was used, because of the complexity of the hydrodynamic regimes and their three-dimensional character. The calculations were performed for the three different hydro-meteorological conditions for each of the five analysed morphological situations of the Odra Estuary. Some results of calculations have been presented.

1. Introduction

Estuaries are formed in the narrow boundary zone between the sea and the land and their nature is changeable. They are meeting places of salt and fresh water, land-borne and sea-borne sediments, and also fresh-water and salt-water flora and fauna. Estuaries are governed by the water level changes at the sea face and by the river flow, which are the main independent variables. Because of their fertile waters, sheltered anchorages, the navigational access and other facilities like tourism they have been the main centres of man's development. The development of trade and industry has led to a large-scale alteration of the natural balance within the estuaries by change of their morphology, making navigation easier for larger ships, and larger scale pollution, as a result of industrialization and population increases.

Their form, extent and depth are constantly altered by erosion and deposition of sediment. Drastic effects result from the raising or lowering of the sea level or human activities. The human activities like dredging, constructing, regulating of fresh-water flow, discharging of pollutant waters and others sometimes affect the systems deeply. To be able to understand and predict these effects it is essential for mankind not to do unnecessary damage to his environment. Knowledge of the hydrodynamic conditions and the exchange of water in estuaries is important for ecological, navigational and water management reasons.

The main problem in studying estuaries is that the river discharge, the sea level and the sediment distribution are continually changing and consequently some estuaries may never, in fact, be steady-state systems, although they may be trying to reach a balance they will never achieve. The complexity makes it difficult to study and describe them. The topography, river discharge, sea level and local winds, constitute important factors that influence the water currents and the rate and extent of mixing of salt and fresh water. The resultant mixing will be reflected in the density structure and the presence of stratification may cause modification of the circulation of water and water exchange between the individual parts of estuaries. The three-dimensional nature of estuaries is of great importance.

Before any particular study can be begun, it is essential to understand the mechanism of the estuary; the way in which the individual parts of the system react with each other and how each affects, or is affected by, the others. The movements of water under the influence of the sea water change and river discharge are closely inter-related with the movement of sediment and are also affected by the wave action and currents in the sea outside the estuary. The effect of saline penetration into the estuaries due to density variations is enhanced by the three-dimensional nature of the flow. All these factors modify the mixing process and must be taken into account when estimating the penetration of salt into the estuary. It is convenient to consider the various components separately, but it must never be forgotten that they cannot act independently.

The boundary shape of the estuarine system is determined by the geomorphology of the land and the properties of all alluvial materials that form the bed and banks of the channels. Usually, the overall boundary shape changes only slowly, though there may be rapid local or short term changes. Gradual changes take place due to the accumulation and re-distribution of river-borne solids. The geomorphology of an estuary basin is, essentially, a fixed boundary condition but the shapes and the depth of channels modified by the flow or human activities can be regarded as a variable boundary.

The influence of the morphology changes on flow conditions, the penetration of salt into the estuary and water exchange in the estuaries are analysed in this paper on the example of the Odra Estuary. The morphology of the Odra Estuary, and especially the Świna Strait, have changed immensely since the beginning of the XVIII century. The consequences of the hydrotechnical reconstruction of the Świna Strait gave rise to the interest in 1880 after the opening of the present

Piastowski Canal. There is no precise information and explanation what the hydrological conditions and water salinity had been like before the work on the Świna Strait was started. There is no record of subsequent changes of the Bay either.

The analyses were performed on basis of data from in situ measurements and the results of calculations. For calculations, the three-dimensional model ESTURO was used because of the complexity of the hydrodynamic regimes and their three-dimensional character. The calculations were performed for the three different hydro-meteorological conditions for each of the five analysed morphological situations of the Odra Estuary.

2. Changes in the Odra Estuary Morphology

The estuarine zone of the Odra estuary extends around 150 km up river, and is a highly complex system of the Odra branches, canals, shallow regions and water reservoirs. Its present morphological situation is shown in Fig. 1. The Odra river flows into Szczecin Bay and subsequently from the Bay to the Baltic Sea through three straits: Peene, Świna and Dziwna. Through the Bay leads a 20 km long and 250 m wide artificially dredged navigational channel with a minimum depth of 10.5 m. Szczecin Bay is supplied with fresh water – ninety-seven percent by the Odra and by several smaller rivers. The depths of the Bay and especially the straits are highly differentiated and changeable in time.

Because of the important role of this region for a long time it has been intensively exploited and changed by man. From the historical data one may conclude that till the end of the XVII century Szczecin Bay was a fresh water reservoir, and the straits were the mouth parts of the Odra river. The mean water level in the Bay was around 0.50 m higher than in the sea (Mielczarski 1987). The inflow of sea water was limited by the shallow and very winding flows. Only during the storm surge situations did the salt sea water flow into Szczecin Bay together with the sea-borne sediments. This situation is designated as S-700.

Situation S-700 was defined on the basis of historical information (IMGW 1980, Osiecimski 1966, Robakiewicz 1993). At this time the Peene in the western parts of the bay was the main, longest and deepest connection of the Bay with the sea. Its depths were more than 6.0 m, only near the sea was the depth only around 2.0 m. The depth of the Dziwna, connecting the eastern part of the Bay with the sea, was in the range of from 2.0 to 4.0 m. The Świna, in the centre of this system was at this period the only natural river (Fig. 2a), without the Piastowski and Mieliński Canals. The depth was from 2.0 to 6.0 m, near the sea the depth was around 2.0 m and there were the sand bars which changed their position depending on the storm conditions. In Szczecin Bay two sub-areas were distinguished, the Large Bay with a maximum depth of up to 8.0 m and the Small Bay with a maximum depth of 6.0 m. The greatest depth was between the Large

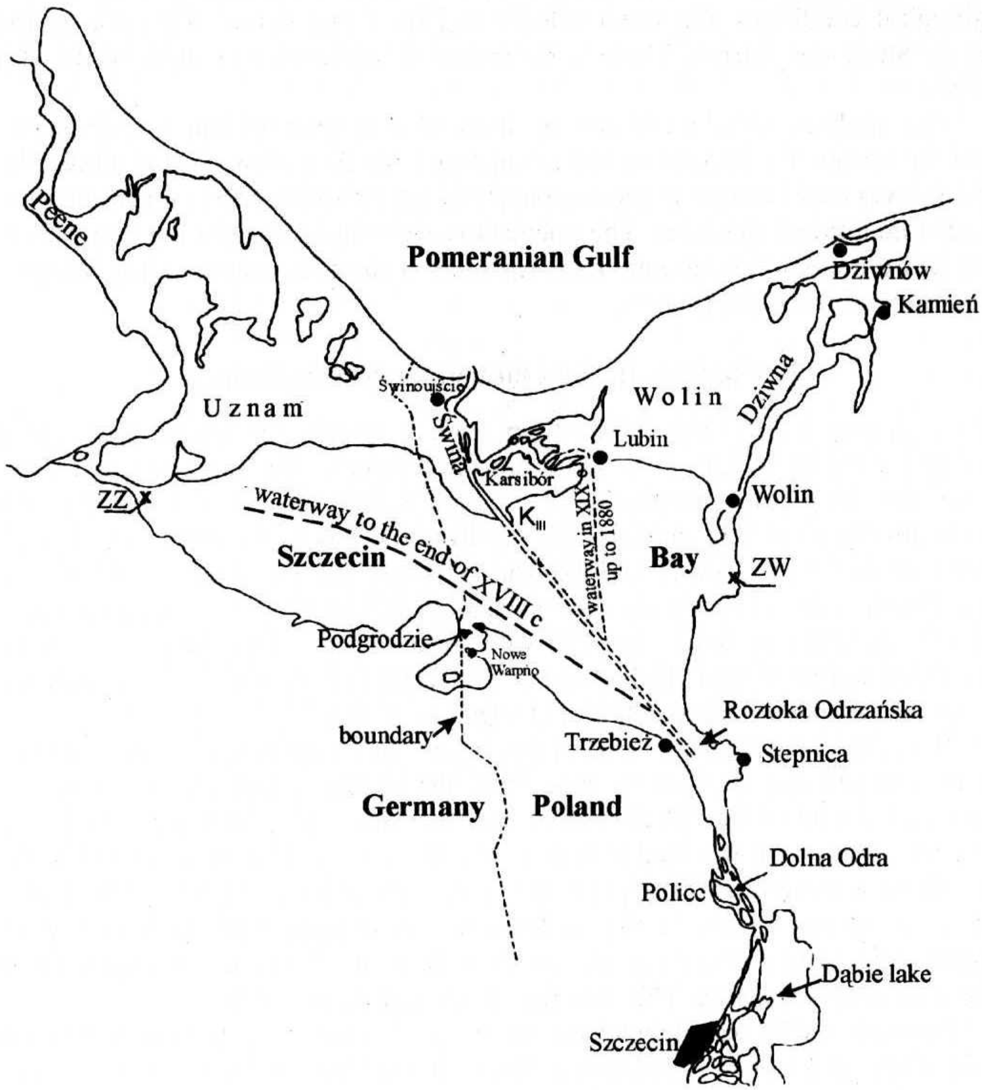

Fig. 1. The Odra Estuary and location of the waterways across Szczecin Bay

and the Small Bay – 9.0 m. Around the coast of the Bay there were shallow parts with depths of less than 2.0 m. The general depth in the Bay did not change for a long time except in the region of man-made navigational canals. In the further analyses which were carried out especially from the point of the Świna Strait, the morphology of the Peene, the Dziwna and Szczecin Bay, except the navigational canal, were without change.

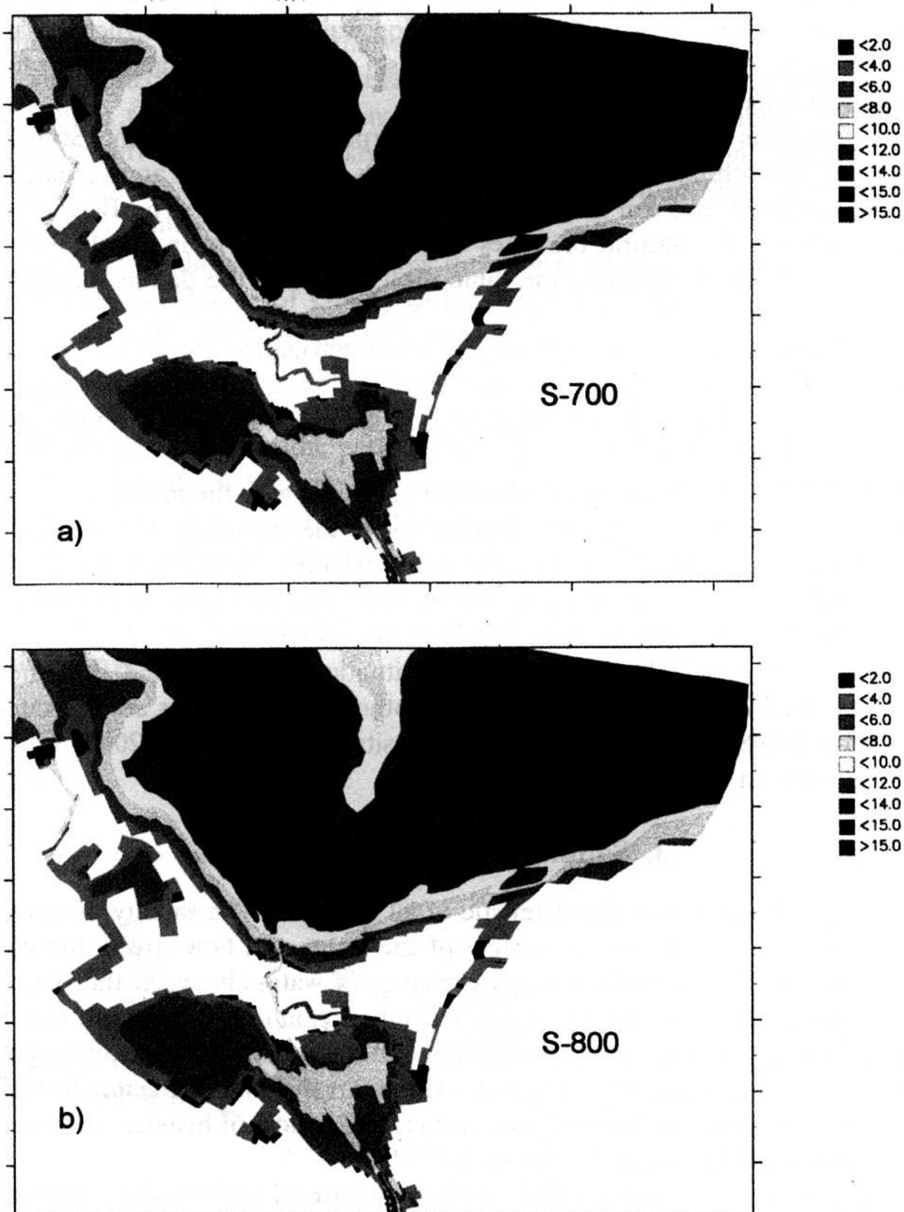

Fig. 2. Morphological situations S-700 (a) and S-800 (b)

From the beginning of the XVIII century, for political and economical reasons, a great deal of work was carried out to obtain the waterway through the Świna Strait. At the end of 1875 the decision was taken to construct the artificial Piastowski Canal and in the 90's the Mieliński Canal. The situation after finishing these two canals was called S-800.

In situation S-800 there was a new morphology of the Świna Strait, which consisted of both natural and manmade canals (Fig. 2b). The approximate length of the strait was 16.5 km and the depths were 6.0 to 7.0 m. The Boczna and the Stara Świna – the natural branches were less than 6.0 m in depth. This shape of the Świna Strait remained the same until now, only the depths have gradually changed.

In situation S-939 the depth of the whole navigation canals was 10.0 m with the deeper parts near the sea in the Zbiorczy Canal, the depth was also 10.0 m across Szczecin Bay. The depths of the Boczna and Stara Świna were respectively around 8.0 and 6.0 m.

At situation S-998 the depth situation conforms with the in situ measurements performed in 1998. The depths are differ due to the erosion and sediment deposits in different parts of the strait and also as the results of dredging work. The depths in the navigation channel along the Świna Strait exceed 12.5 m and in some places even 15.0 m, across the Szczecin Bay they are around 10.5 m.

At situation S-2000, the perspective situation, it is assumed that the depth through the Świna Strait is 14.5 m and in other regions depths are the same as at situation S-998. These five morphological situations (Jasińska 2000) were taken into account in the calculation and analysis.

3. Salinity of Water in Szczecin Bay

Exchange of waters is a characteristic of all estuaries. The salinity of water is the parameter which indicates the origin of the water and how strong the exchange processes are. In the Odra Estuary exchange of waters between the Bay and the sea varies from one strait to another. The interaction of fresh and salt water in the Odra Estuary generates water circulation and transport patterns typical of classical estuaries. The circulation is often of a three-dimensional character. In the straits an outflow of fresh water along the surface and inflow of heavier, seawater along the bottom can be observed (Jasińska 1991).

In Szczecin Bay characteristic of the structure of saline waters is its inhomogenity especially in the horizontal plane. This is connected with the transitory character of the Bay. In the shallow areas of the Bay in the vertical plane salinity changes are negligible due to turbulent processes of mixing and diffusion caused by currents and waves. In the deeper areas of the bay as well as in the waterway and on the deep connection between the Large and the Small Bay, salinity gradients are sometimes observed. During strong stormy inflows seawater flows through the whole cross-section of the straits, especially through the Świna Strait and further along the deep waterway and into the deeper areas of the Bay. Sometimes saline water crosses the whole Bay and within the Bay fronts in the vertical and horizontal planes between the sea and the Bay water appear. In the deeper regions the saline water may persist for some time and lenses of saline water remain surrounded by the Bay water. The lenses of remaining saline waters gradually disappear due to mixing and turbulent diffusion or they are displaced by currents and winds in different direction.

The problem is therefore if and how the change of morphology of the Odra Estuary affects the change of salinity of the Bay water? According to historical information (IMGW 1980, Mielczarski 1987) at the end of the XVII century the water in Szczecin Bay was land-water. The first information concerning the salinity of Szczecin Bay comes from the beginning of the XX century. From the measurements performed in the period 1969–1971 (Fig. 3) it was stated (IMGW 1980) that the salinity of Szczecin Bay water changes of from 0.0 to 3.0 psu, with the maximum frequency of 0.1 psu. The salinity of water in the range from 0.0 to 1.0 psu is typical for the bay and river water. In the Small Bay the maximum frequency of salinity was in from 0.5 to 0.7 psu, which is typical for the bay water, in the Large Bay the maximum frequency was between 0.1 to 0.5 psu which is closer to the river water.

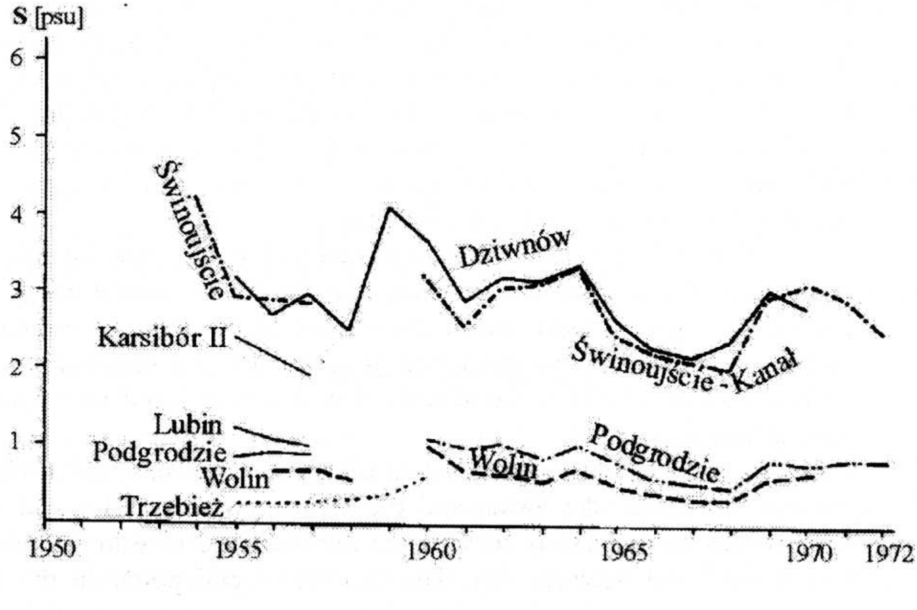

Fig. 3. Mean monthly salinity of water in Szczecin Bay, measured data

water salinity in Szczecin Bay determined on the basis of the data at Podgrodzie from the periods: 1955–1957 and 1960–1972 was 0.83 psu. The minimum values of salinity during these periods were 0.1–0.2 psu, which are characteristic for river waters. The maximum values are very different and depend on the points of measurements, sometimes they are equal to the salinity of sea water (Jasińska 1995). It happens near the outlets of the straits to Szczecin Bay and in the deeper areas of the Bay as well as in the waterway and deep connection between the Large and the Small Bay.

Comparing the data from measurements performed at many points of Szczecin Bay and at different times it was stated that the salinity of water in Szczecin Bay had gradually increased from the beginning of the XVIII century to the first half of the XX century. During the last 50 years there has not been any marked increase of the water salinity in Szczecin Bay. The testing of flora and fauna has also not indicated an increase in water salinity (IMGW 1980, Wiktor 1972).

4. Numerical Model ESTURO

The complexity of the processes and their three-dimensional characteristics need the use of a three-dimensional model of high resolution in the vertical and horizontal plane in order to receive detailed information about the flow and exchange conditions in the Odra Estuary. The three-dimensional numerical model of the Odra Estuary ESTURO used in the calculation was set-up in the Institute of Hydroengineering of the Polish Academy of Sciences (IBW PAN) based on the TRISULA (and delft3Dflow) package (Delft 1995, 1996). For the calibration and verification of the numerical model the data gathered during several in-situ measurements were used. The results of the calibration and verification of the ESTURO model are presented in Jasińska and Robakiewicz's (1999) paper. The ESTURO model was used for the description of water level changes as well as velocity and salinity distributions in that region for different morphological and hydro-meteorological conditions in the Odra Estuary.

The numerical model ESTURO solves the equations of the flow for incompressible fluid, under the shallow water assumption. In the horizontal plane, an orthogonal curvilinear grid is used and in the vertical plane sigma co-ordinates are introduced. For each layer the equations of continuity and momentum are solved. In this approach a vertical momentum equation is reduced to a hydrostatic pressure gradient.

The area of the model (Fig. 4) extends over the part of the Pomeranian Gulf, the three straits: the Peene, the Świna and the Dziwna, Szczecin Bay and the Odra to Police which was necessary to simulate the exchange of water between the Pomeranian Gulf and Szczecin Bay. The number of grid points in the horizontal plane on the surface is 8140 (110×74), in the vertical plane 8 layers were introduced. The thickness of the layers was changeable depending on the

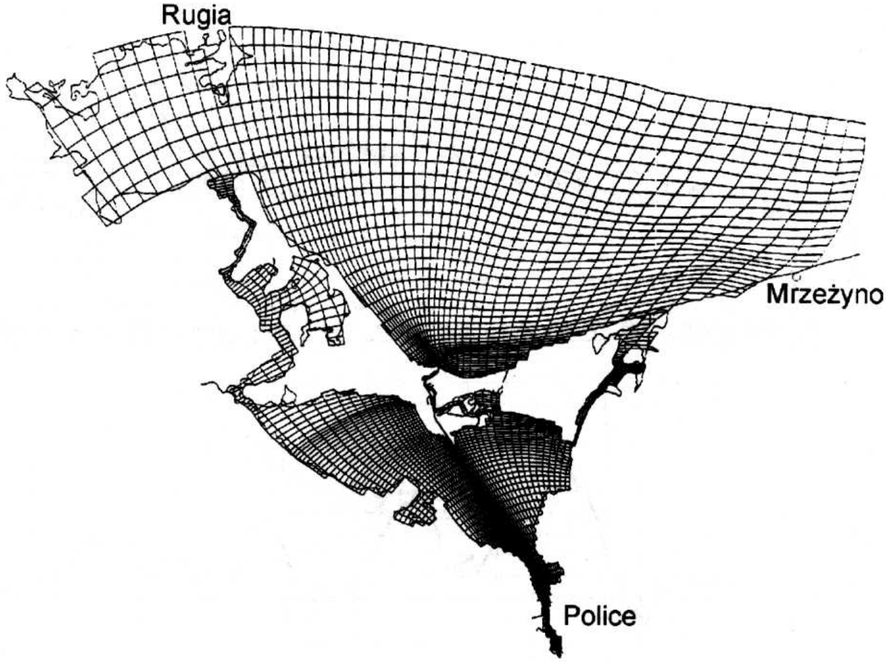

Fig. 4. Horizontal descretization of the model ESTURO

local depth and chosen percentage distribution. The time step was 60 s taking into account the Courant number.

The five different morphological conditions for which the calculations were performed were described above (S-700 to S-2000). The calculations were made for three different hydro-meteorological conditions that occurred during the periods: 31^{st} of May to the 13^{th} of June 1988, 10^{th} to 20^{th} of October 1985 and 31^{st} of October to 8^{th} of November 1995. These are the representative conditions for the flow characteristics in the Odra Estuary which present the calm, mean and very strong stormy conditions and water level changes (Fig. 5). A detailed description of the all hydro-meteorological conditions is presented in the report (Jasińska 2000).

5. Results of Calculations

The influence of morphological changes on flow and water exchange in the Odra Estuary was presented on the basis of the results of calculations carried out for three different hydro-meteorological conditions and each of the five analysed morphological situations in the Odra estuary. The data required to describe the boundary and initial conditions was acquired on the basis of the measurement data and historical information. On the basis of calculations performed for each of the analysed examples parameters as follows were described: the water levels changing

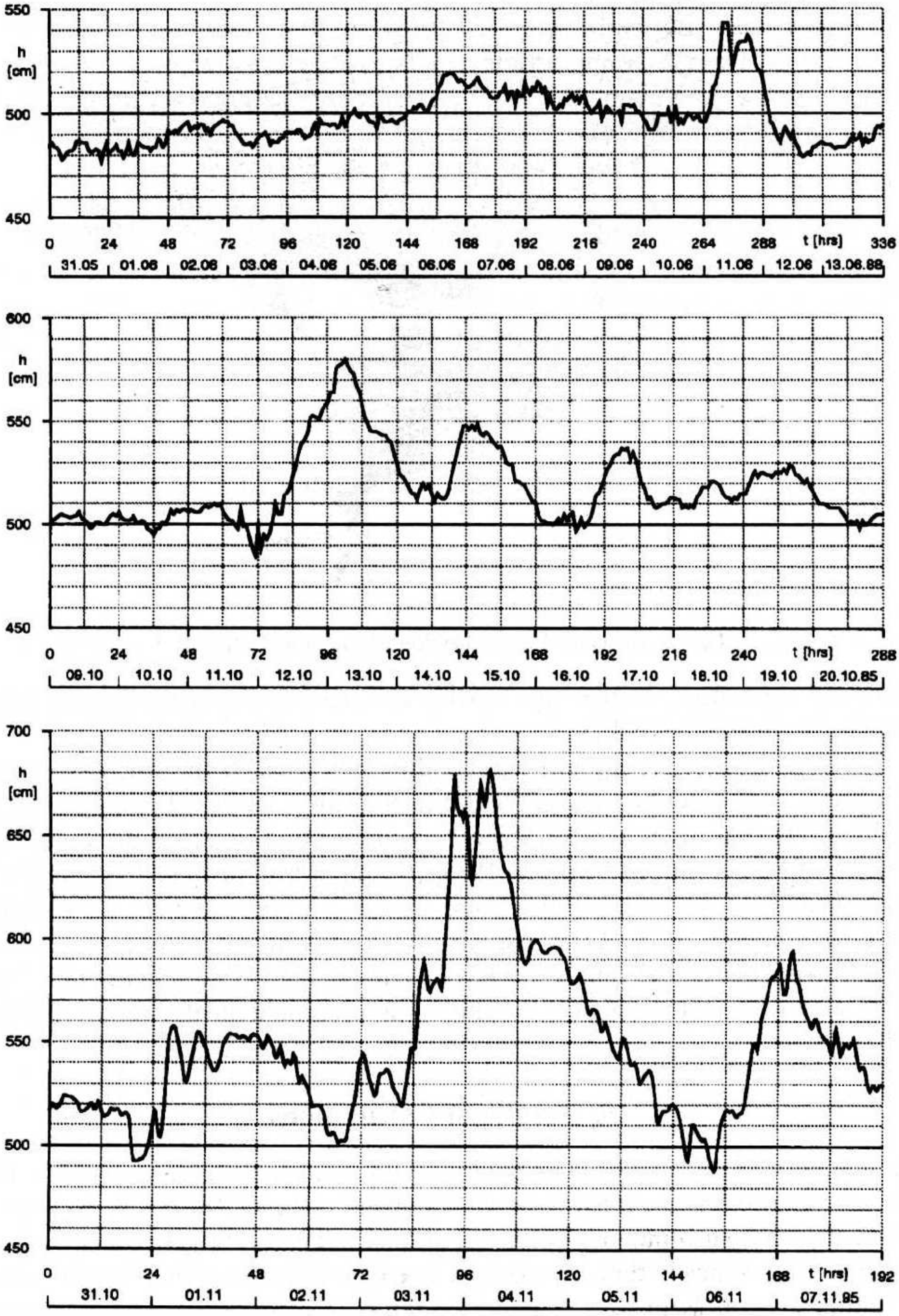

Fig. 5. Measured time series of water levels at Świnoujście

at the sea boundary and in Szczecin Bay, the changes of water slopes between the Bay (Karsibór III) and the Pomeranian Gulf (Świnoujście), flows through the straits and the velocity and salinity distributions at several chosen points situated along the Świna Strait (Fig. 6) and around Szczecin Bay (Fig. 1). The results for the analysed morphological situations and hydro-meteorological conditions were included in the report (Jasińska 2000). In this paper only some characteristic results have been presented.

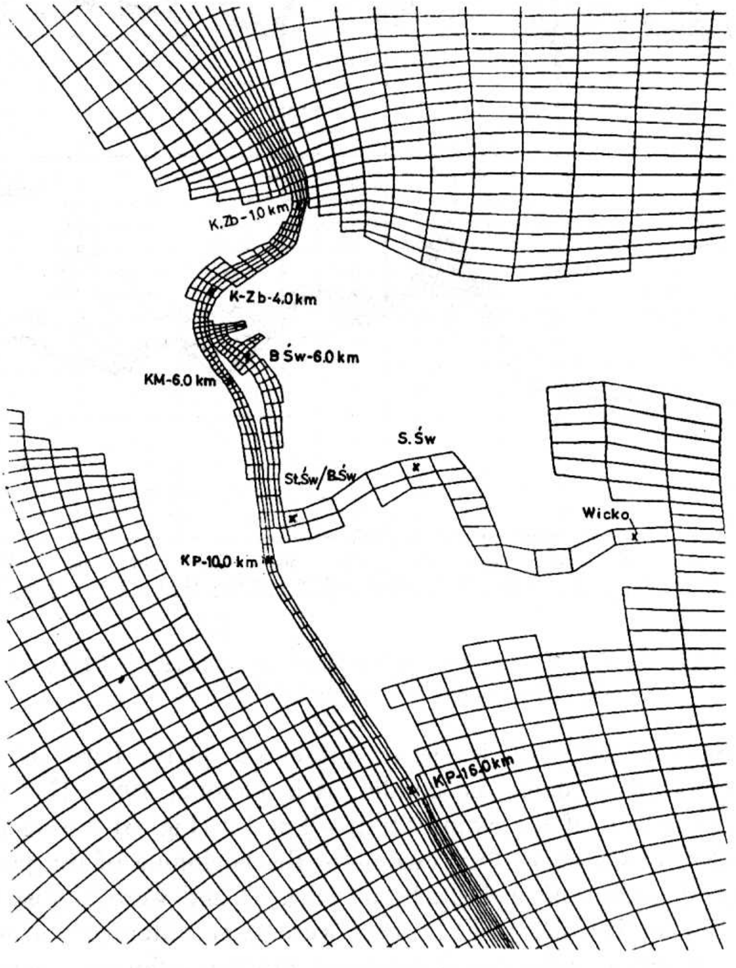

Fig. 6. Horizontal descretization and profiles in the region of the Świna Strait

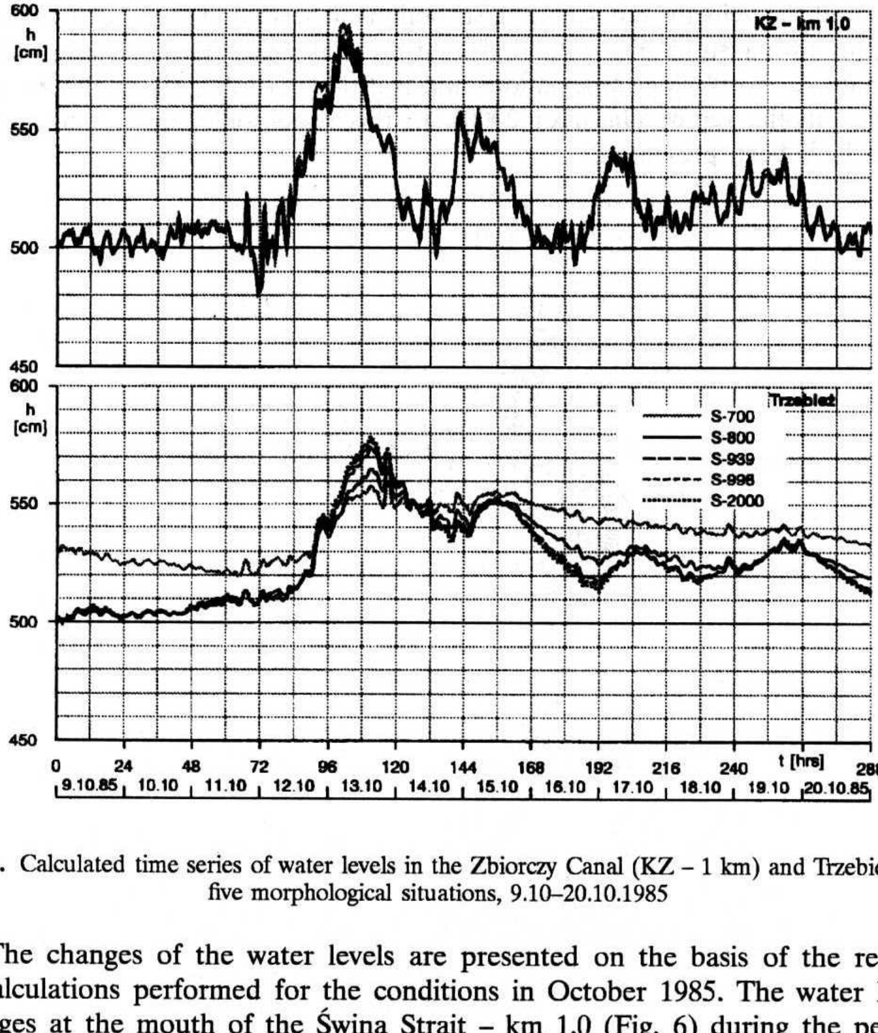

Fig. 7. Calculated time series of water levels in the Zbiorczy Canal (KZ – 1 km) and Trzebież for five morphological situations, 9.10–20.10.1985

The changes of the water levels are presented on the basis of the results of calculations performed for the conditions in October 1985. The water level changes at the mouth of the Świna Strait – km 1.0 (Fig. 6) during the period from 9^{th} to 20^{th} of October 1985, except for the beginning of the period, were noticeable in all morphological situations (Fig. 7) and were almost the same. In Szczecin Bay, at Trzebież (Fig. 1) there were some differences in water level changes for different morphological situations. Greater differences were between situation S-700 and others. The differences were mainly caused by the shallow and meandering shape of the canals which limited the outflow and inflow of the water. Similar differences in water level changes were observed during calm and strong hydro-meteorological conditions. The decrease of mean water level in Szczecin Bay was a result of constructing the artificial Piastowski and Mieliński Canals and increase of their depths.

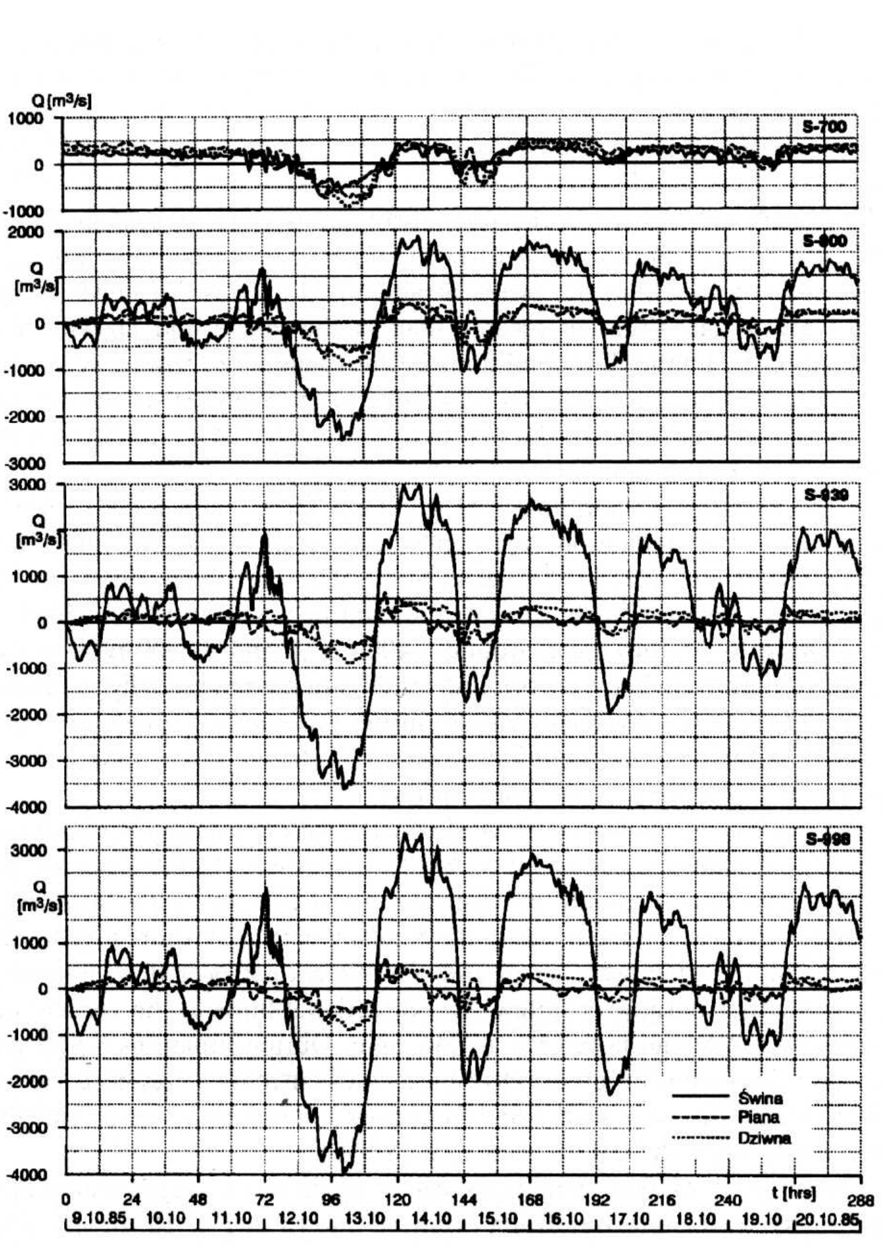

Fig. 8. Calculated time series of flows in Świna, Piana and Dziwna, 9.10 – 20.10.1985, for four morphological situations, (+) – outflow and (–) – inflow

The next problem studied was the relation between water flows in the straits and changes of their morphology. The change of flow conditions was also presented on the basis of calculations performed for the hydro-meteorological conditions in October 1985 (Fig. 8). In the S-700 situation the flows in all straits were very similar. Higher flows were observed in the Peene and Dziwna because of their greatest depth in this period. The directions of the flows changed in accordance with changes of water levels and water slopes between the sea and Szczecin Bay. Discharges were in the range of from +500 m^3/s (outflow) to around −1000 m^3/s (inflow).

Noticeable differences in the flow distributions were present in the situation S-800. The construction of the Piastowski and Mieliński Canals with deepening of the waterway throughout the Świna Strait caused increase of flows in the Strait, which were in this situation greater than in the Peene and Dziwna Straits. In the situation S-800 the flow conditions in the Peene and Dziwna were almost the same as in the situation S-700. The discharge in the Świna Strait during the strong inflow reached −2500 m^3/s. The inflow conditions in the Świna Strait were more frequent than in the situation S-700.

In the next tested morphological situations (S-939 and S-998) the character of changes of flow conditions was similar to that at S-800, but with an increase of discharge magnitudes in the Świna Strait. The maximum inflow in the Świna Strait in the situation S-939 exceeded −3500 m^3/s and outflow +3000 m^3/s. In the situation S-998 they were around −4000 m^3/s and +3300 m^3/s respectively. The flow differences between the last tested situations gradually decreased. The increase of flows was especially visible during extreme hydro-meteorological conditions. Changes in flow conditions generate a change of currents and exchange of water between the sea and Szczecin Bay.

The results of calculations show significant differences in distributions of currents (Fig. 9) between the situation S-700 and others. In the situation S-700, in the Zbiorczy Canal – 1.0 km, the distributions of currents in the surface and bottom layers were very similar and almost steady with only short term oscillations. The current velocities were small and one directional over the whole depth, i.e. there was either outflow or inflow. Two-directional flows in the vertical plane occurred very rarely and lasted for a short time. During situations S-800 and S-998 flow conditions were different. Distributions of currents were more variable, discharge magnitudes were higher and frequencies of two-directional flows increased considerably when the depths increased (S-998).

The changes of flow conditions cause significant changes especially in the influx of sea water into the Świna Strait, as shown in Fig. 10. In situation S-700 the distributions of salinity in the surface and bottom layers at the point Zbiorczy Canal – 1.0 km were the same. The inflow of water with a salinity of less then 3.0 psu was observed at the end of testing period, after the inflow with velocity of around −0.5 m/s (Fig. 9). In the situations S-800 and S-998 under the same hydro-meteorological conditions the inflow of salt sea water of salinity $S = 7.0$ psu occurred at the beginning of the period and started first in the bottom layer. The frequency of inflow of salt water into the Świna Strait increased considerably with increase in depth (S-998). The flow was very often stratified, also in situations

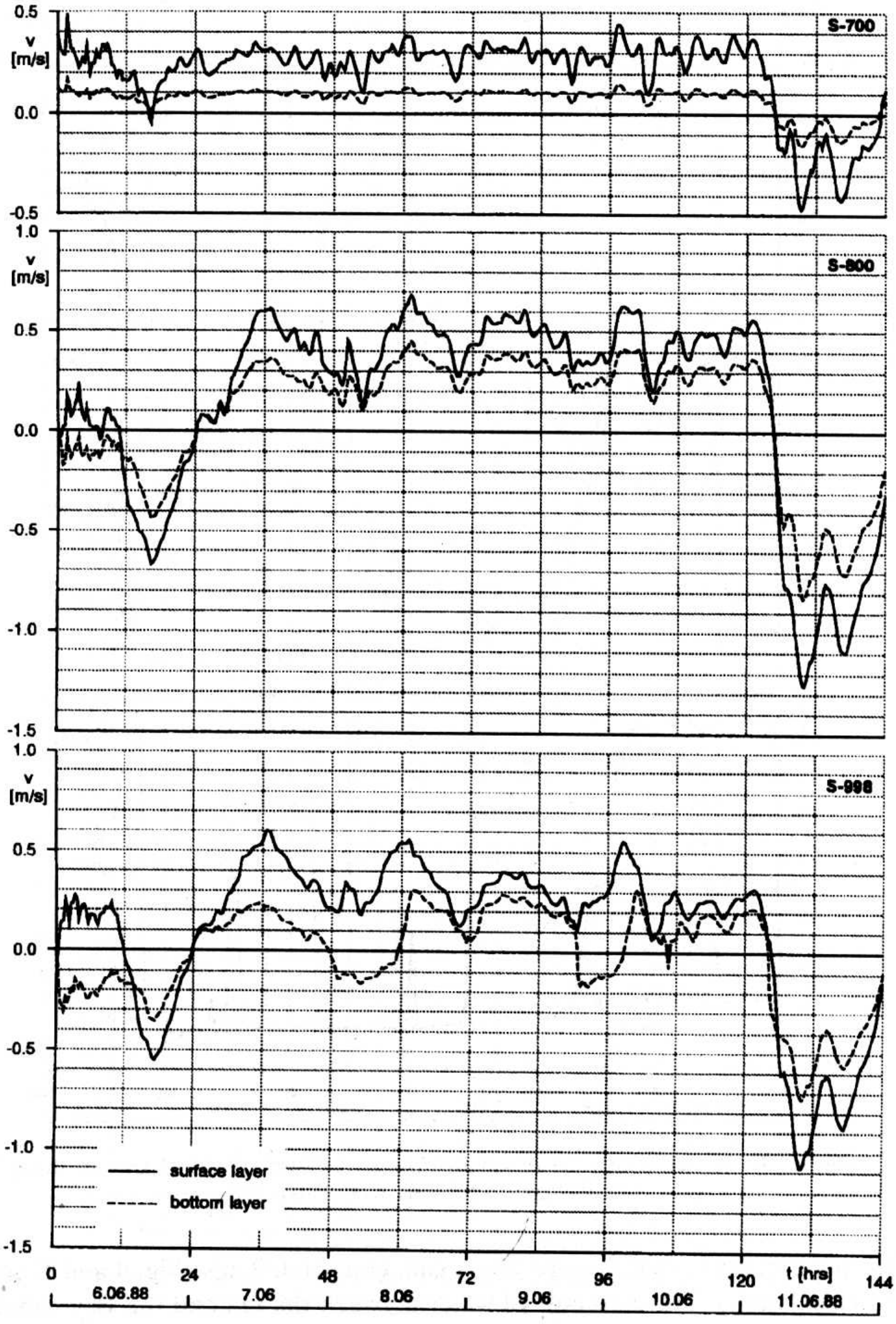

Fig. 9. Calculated time series of current velocity close to the Świna mouth for three morphological situations, (1 km) 6.06–11.06.1988, (+) – outflow and (–) – inflow

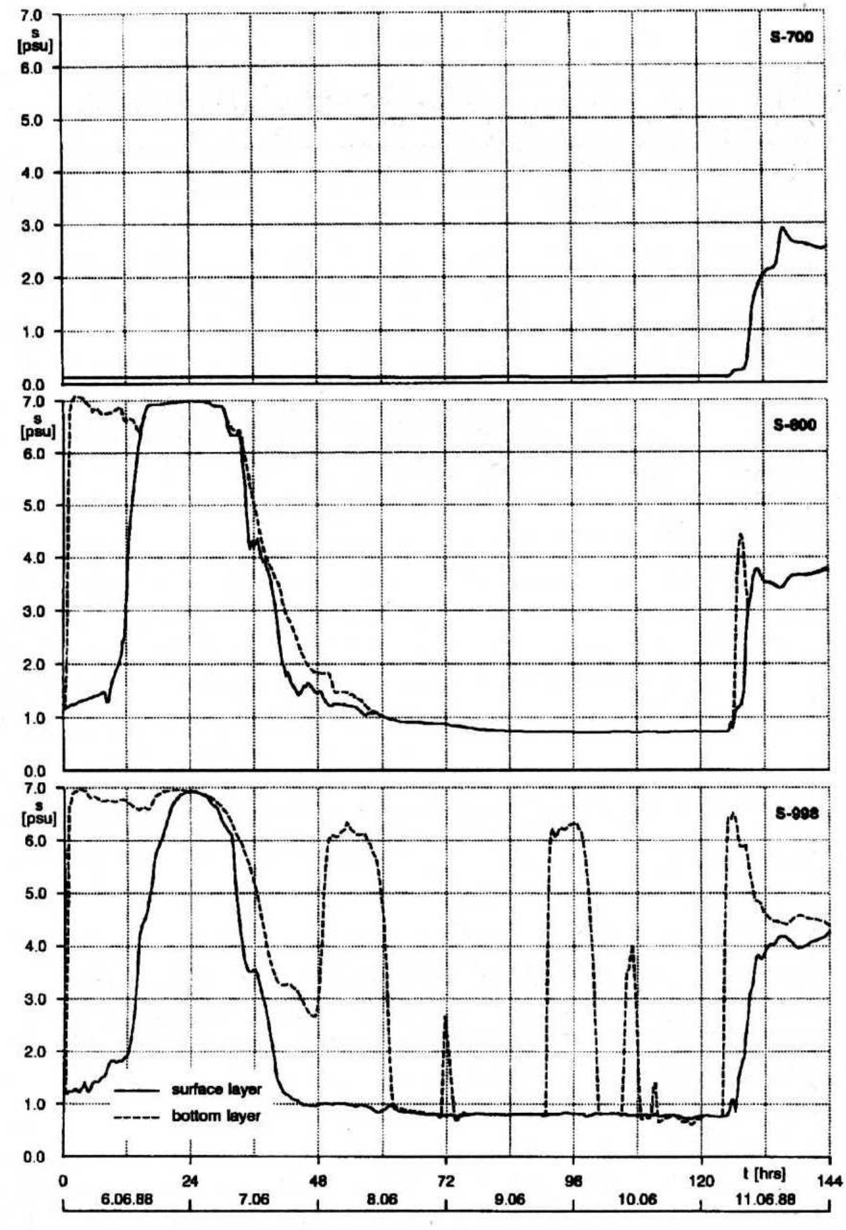

Fig. 10. Calculated time series of salinity close to the Świna mouth (1 km) for three morphological situations, 6.06–11.06.1988

when the current velocities were very small, close to 0.0 m/s (Fig. 4 and 5, see 72 hour calculation). The exchange of water between the sea and the Bay increased with the deepening of the canals. The outflows and inflows in the Świna Strait are now easier, the greatest differences occurred between the situations S-700 and

S-800. The differences between the situations S-998 and S-2000 were very small (Jasińska 2000).

Longitudinal distribution of salinity in the Świna Strait are shown in Figs. 11 and Fig. 12 for situation of stronger hydro-meteorological conditions which were

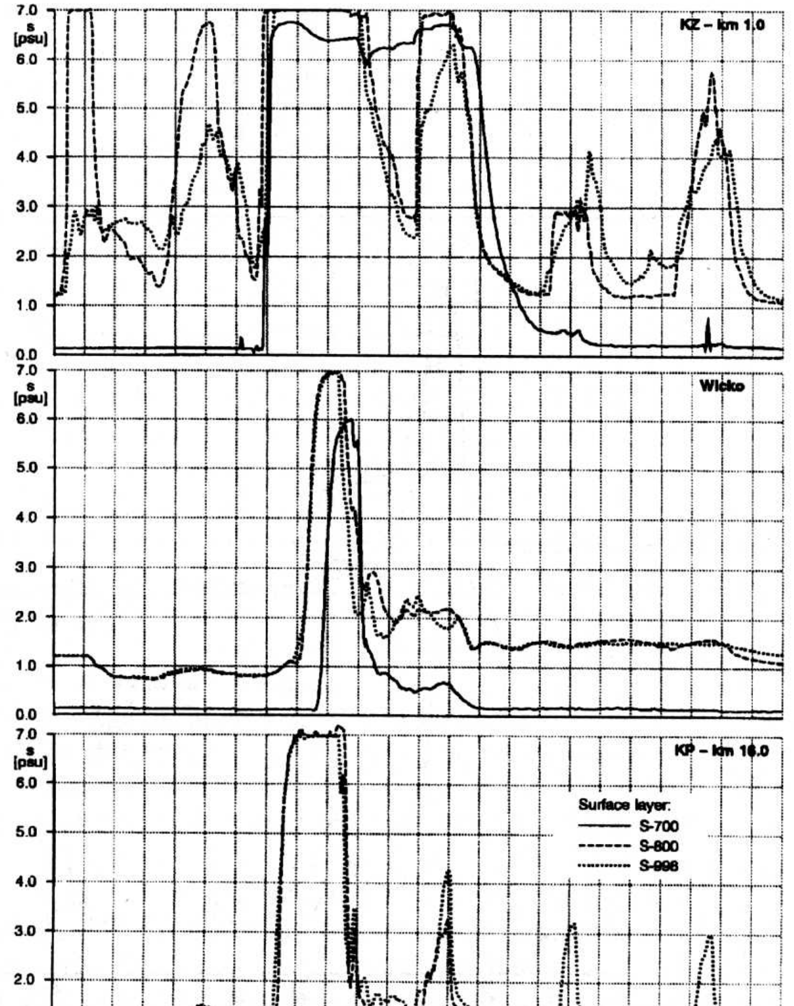

Fig. 11. Calculated time series of salinity distributions in surface layer, near the sea (KZ – 1 km) and the Bay (Wicko, KP – 16 km), 9.10–20.10.1985

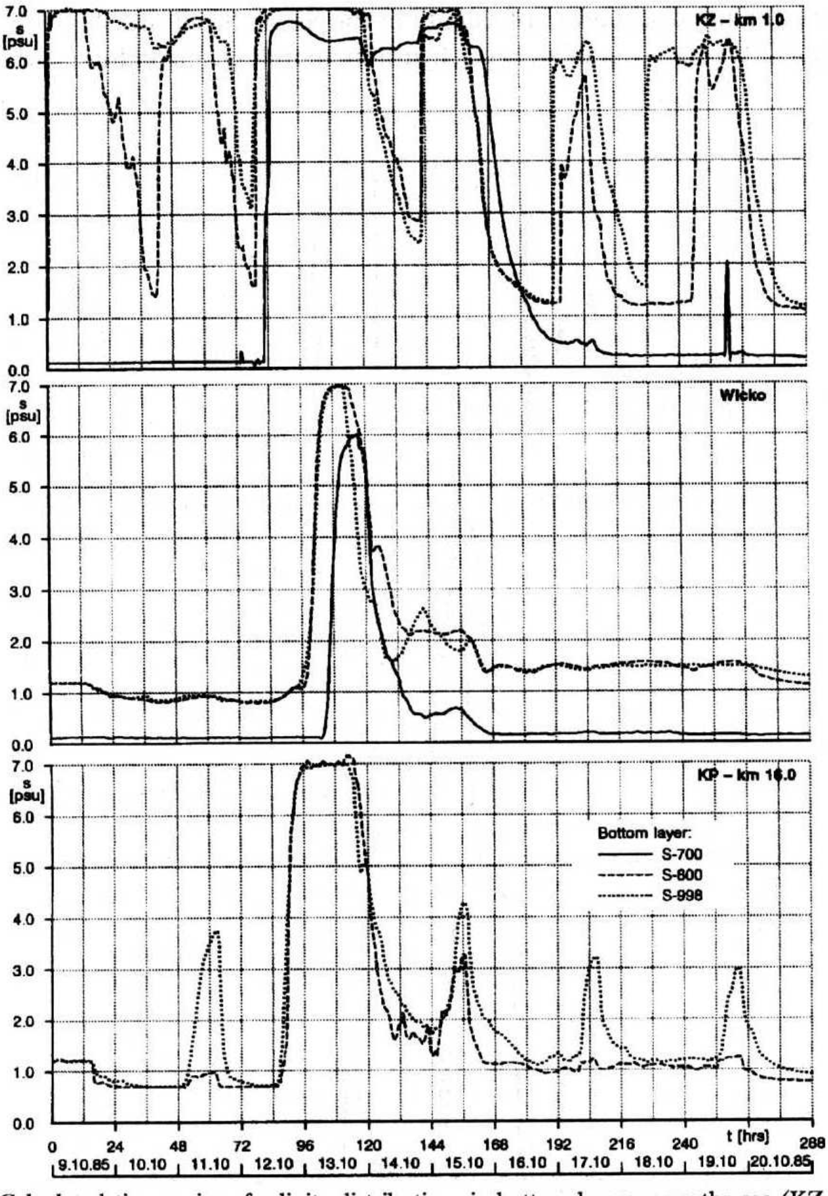

Fig. 12. Calculated time series of salinity distributions in bottom layers, near the sea (KZ – 1 km) and the Bay (Wicko, KP – 16 km), 9.10–20.10.1985

observed in October 1985. The results are presented for situations S-700, S-800 and S-998 and at the points: Zbiorczy Canal – km 1.0, Wicko and Piastowski Canal – km 16.0. The last two points are very close to Szczecin Bay. Similarly, as stated for the calm hydro-meteorological conditions, the frequency of the influx of salt water into the Świna Strait and also Szczecin Bay increased considerably at situation S-800 as compared with S-700, when the artificial canals were build, and also due to further deepening of the canals (S-998). There are also differences in distributions of salinity in the surface and bottom layers, especially in the Zbiorczy Canal, indicating that stratified flows occur and that in the Świna Strait a wedge of salt water is formed more often after deepening of the canals. At situation S-998 the inflow of sea water reached Szczecin Bay more frequently through the Piastowski Canal than through Stara Świna (Wicko), this being noted in the horizontal distribution of the water salinity.

The horizontal distributions of the water salinity, for extreme hydro-meteorological conditions, which occurred in November 1995 are shown in Figs. 13–14. During the very strong influx (4.11.95) the salt sea water was advected through the Świna and spread into the Bay (Fig. 13). Comparing the results for different morphological situations we can see that the spreading of salt water in the Bay increased very strongly. The differences in the horizontal distributions of the water salinity in the surface layer, between the situation S-700 and S-800, were observed near the Wicko and of course, near the Piastowski Canal. At the situation S-700 the inflow occurred only through the Stara Świna (Wicko) and was smaller than at S-800. Similar differences in the horizontal distributions of the water salinity appear between the situations S-800 and S-939. There was a stronger influx of salt water into Szczecin Bay through the Piastowski Canal. Influx through the Stara Świna in both situations was very similar. The differences in the influx of sea water into Szczecin Bay between the situations S-939 and S-998 were very small. At each point, except S-700, there were differences in the distribution of salinity between the surface and bottom layers (Fig. 13b). In the bottom layers the influx of salt water was in all situations stronger.

After the strong outflow (6.11.95) in all checked situations the Świna Strait was filled with mixing bay water (Fig. 14). This was advected into the Pomeranian Gulf and spread into the Gulf. The range of spreading the mixed water was different for all situations tested and increased with increase of the depth of the canals. In all situations in surface (Fig. 14a) and bottom layers (Fig. 14b) there were significant differences between the spreading of mixed and fresh water. The bay water spreading is easier on the surface than at the bottom. In Szczecin Bay there were also differences of salt water distributions between the surface and bottom layers. In the Bay the salt water stays longer in the bottom layers and due to mixing processes spreads laterally in the Bay. The lenses of more salted water move in the Bay (Fig. 14b) in accordance with water currents and wind conditions. The mixing processes cause gradual decay of the salt water in the lenses. These results prove that the outflows and inflows in the Świna Strait are easier now than in the past.

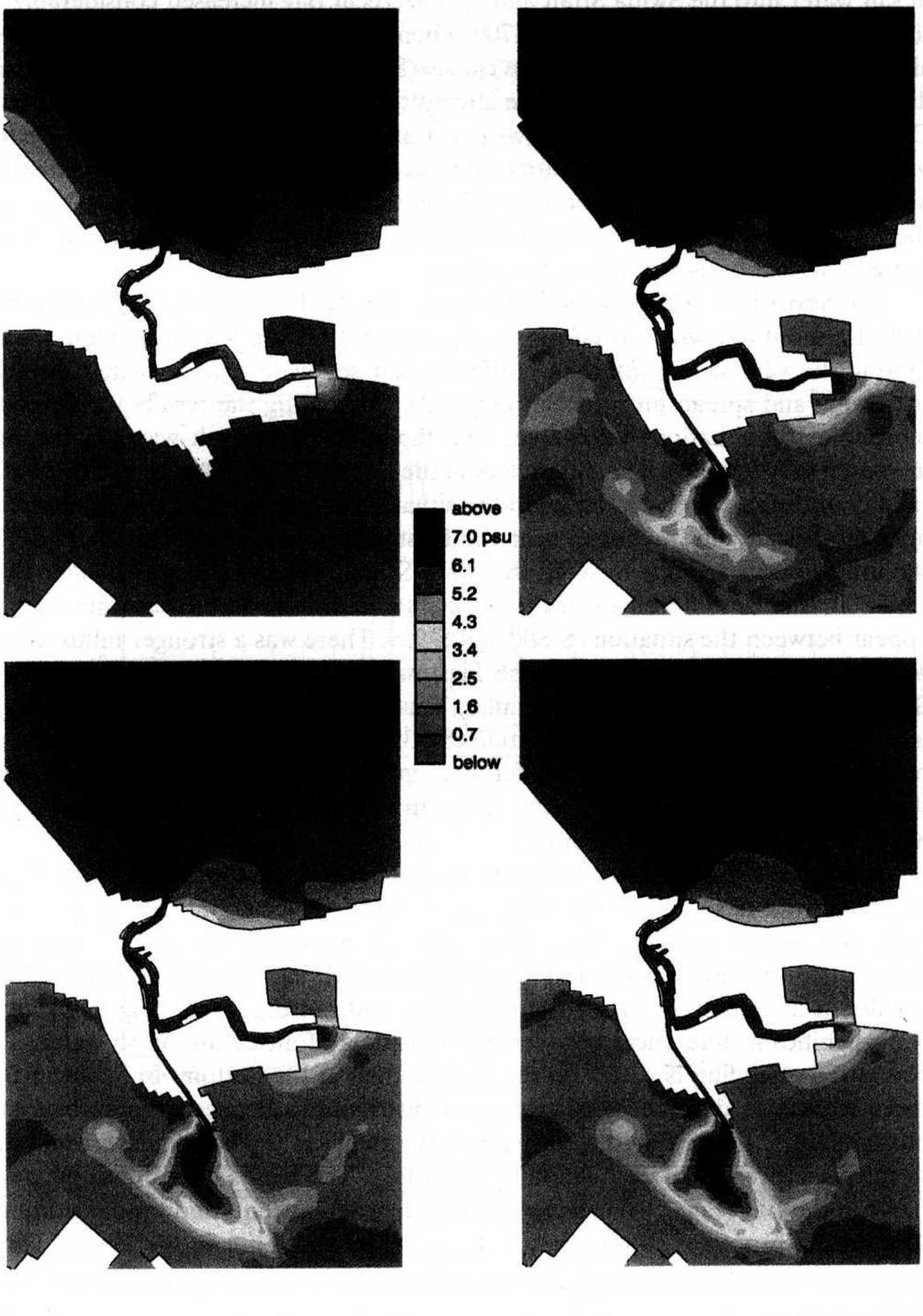

Fig. 13a. Calculated horizontal salinity distributions for four morphological situations during the inflow conditions – 4.11.1995, surface layer

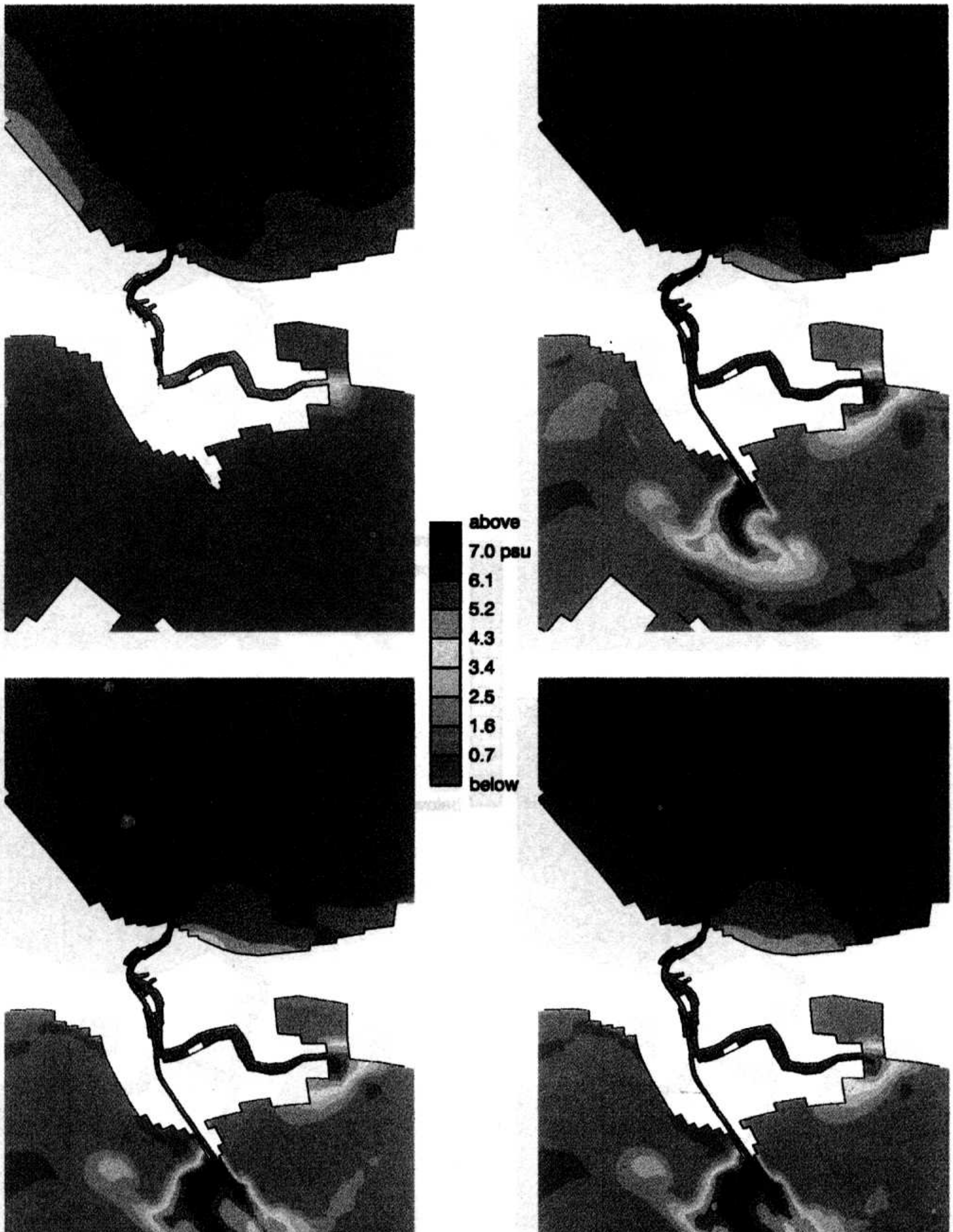

Fig. 13b. Calculated horizontal salinity distributions for four morphological situations during the inflow conditions – 4.11.1995, bottom layer

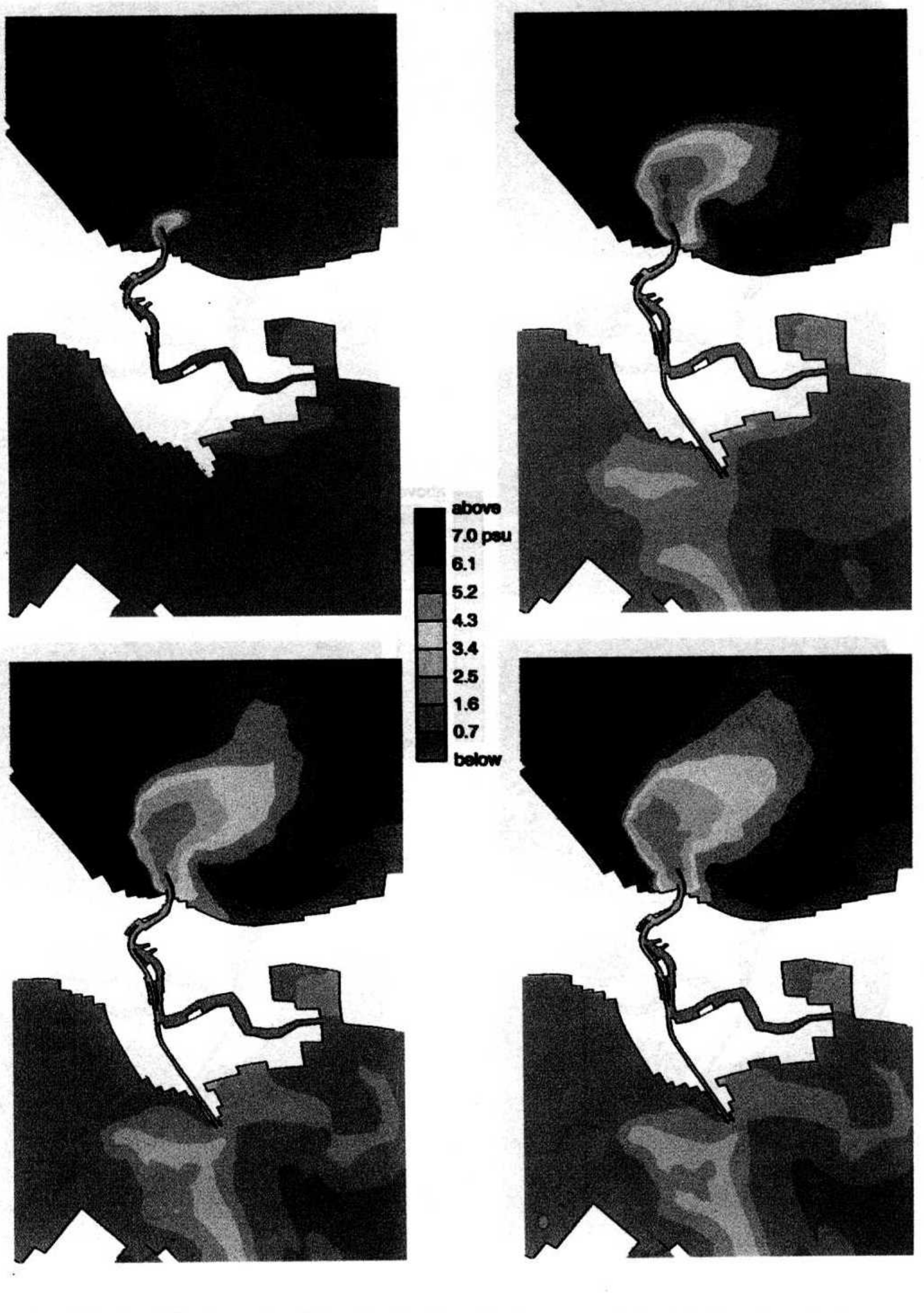

Fig. 14a. Calculated horizontal salinity distributions for four morphological situations during the outflow conditions – 6.11.1995, surface layer

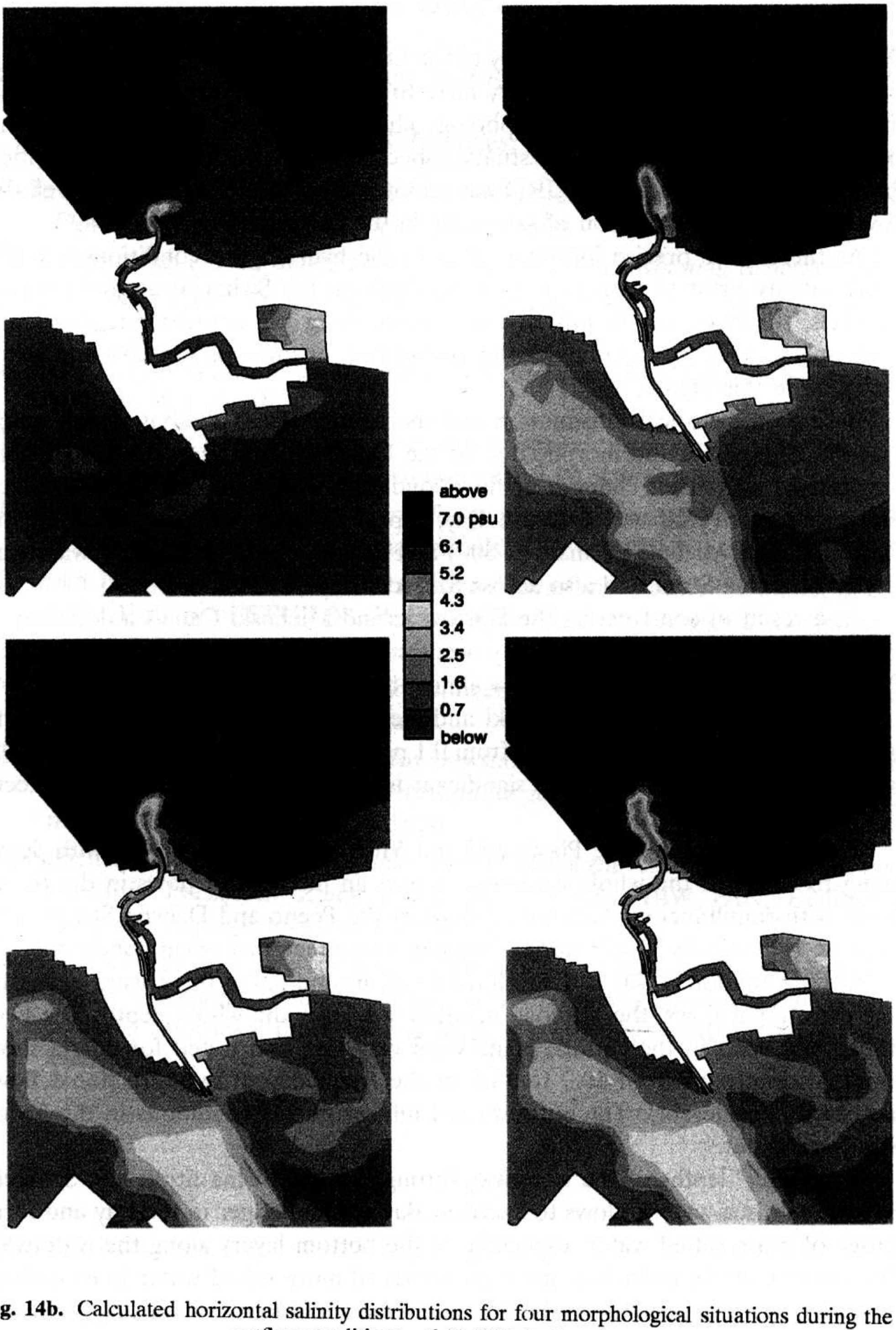

Fig. 14b. Calculated horizontal salinity distributions for four morphological situations during the outflow conditions – 6.11.1995, bottom layer

6. Conclusions

Due to very complicated morphology of the Odra Estuary the flow conditions and water exchange in the Odra Estuary have to be treated three-dimensionally. To simulate the influence of the morphology changes on the flow phenomena and exchange problems in the Odra Estuary, especially in the Świna Strait, the verified three-dimensional model ESTURO was adopted. This model reproduced well the flow phenomena and motion of salt water in the Odra Estuary.

As there is no precise information as to the hydrological conditions and the water salinity prior to commencement of work on the Świna Strait and also afterwards, therefore the results of calculations using the approximate data may show only a tendency to influence the morphology changes on the flow and water exchange in this region.

Basing on historical information and the results of calculations it was stated that the changes of the morphology of the Odra Estuary from the XVIII century caused significant changes of flow conditions and water exchange between the Pomeranian Gulf and Szczecin Bay, especially after the completion of the Piastowski and Mieliński Canals (S-800) and deepening to 10 m of the waterway along the Świna Strait and also across Szczecin Bay (S-939).

As a result of constructing the Piastowski and Mieliński Canals a decrease of the mean water level in Szczecin Bay occurred. The mean water levels in Szczecin Bay and in the Świna Strait are now almost the same.

After constructing the Piastowski and the Mieliński Canals the mean salinity of water in Szczecin Bay increased from 0.1 psu – typical for inland waters - to 0.7 psu. During the last 50 years no significant increase of water salinity in Szczecin Bay has been observed.

The construction of the Piastowski and Mieliński Canals together with deepening to 7.0 m of the whole waterway caused an increase of flows in the Świna Strait with simultaneous decrease of flows in the Peene and Dziwna Straits. The increase is especially visible during extreme hydro-meteorological conditions.

In the situation S-700 at a depth Świna of around 3.0 m there were generally one directional flows, the outflow or inflow was over the whole depth. The two-directional flows in the vertical plane were very rare and lasted for only a short time. At depths of from 10.0 to 14.5 m the frequency of two-directional flows increased considerably. The outflows and inflows in this conditions in the Świna Strait are easier.

At greater depths of the waterway throughout the Świna Strait and Szczecin Bay the salt, sea water inflows to Szczecin Bay remain longer in the Bay and form lenses of more salted water, especially in the bottom layers along the waterway. The currents in Szczecin Bay move the lenses of more salted water in its eastern or western part, depending on the flow and wind conditions. The mixing processes cause decay of the salt water in the lenses.

The changes of depth of from around 10.0 m to 14.5 m in the waterway throughout the Świna Strait do not cause significant changes in flows and water exchange during average and extreme hydro-meteorological conditions.

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