Chapter 3
Water & Sediments

Water ... approximately 70 percent of the earth's surface is covered by it. It makes up approximately 80 percent of our total body weight. Without it, we cannot live. Perhaps, because its presence is so pervasive in our lives, we tend to think of water as homogeneous rather than a substance with extremely diverse characteristics and properties.

In the natural environment, water is never pure. It tends to hold other substances in solution and easily enters into various chemical reactions. As the universal solvent, water is an important environmental medium. Water normally contains dissolved gases, such as oxygen, and a variety of organic (containing carbon) and inorganic materials. The concentration and distribution of these substances can vary within a single body of water. Add differences in temperature and circulation, which can enhance or retard certain chemical reactions, and the variety of possible water environments vastly increases.

Of all bodies of water, estuarine systems offer the greatest physical variability in water composition. An estuary, according to oceanographer Donald W. Pritchard, is a " ... semi-enclosed body of water which has free connection with the open sea and within which sea water is measurably diluted by freshwater from land drainage." Within an estuary, freshwater mixes with salt water, with each contributing its own chemical and physical characteristics. This creates a range of environments that supports a wide variety of plants and animals.

• Water: Salinity, Temperature and Circulation

The distribution and stability of an estuarine ecosystem, such as the Chesapeake Bay, depends on three important physical characteristics of the water: salinity, temperature and circulation. Each affects and is affected by the others.

Salinity is a key factor affecting the physical make-up of the Bay. Salinity is the number of grams of dissolved salts in 1,000 grams of water. Salinity is usually expressed in parts per thousand (ppt). Freshwater contains few salts (less than 0.5 ppt) and is less dense than full strength seawater which averages 25-30 ppt. Salinity increases with depth. Therefore, freshwater tends to remain at the surface.

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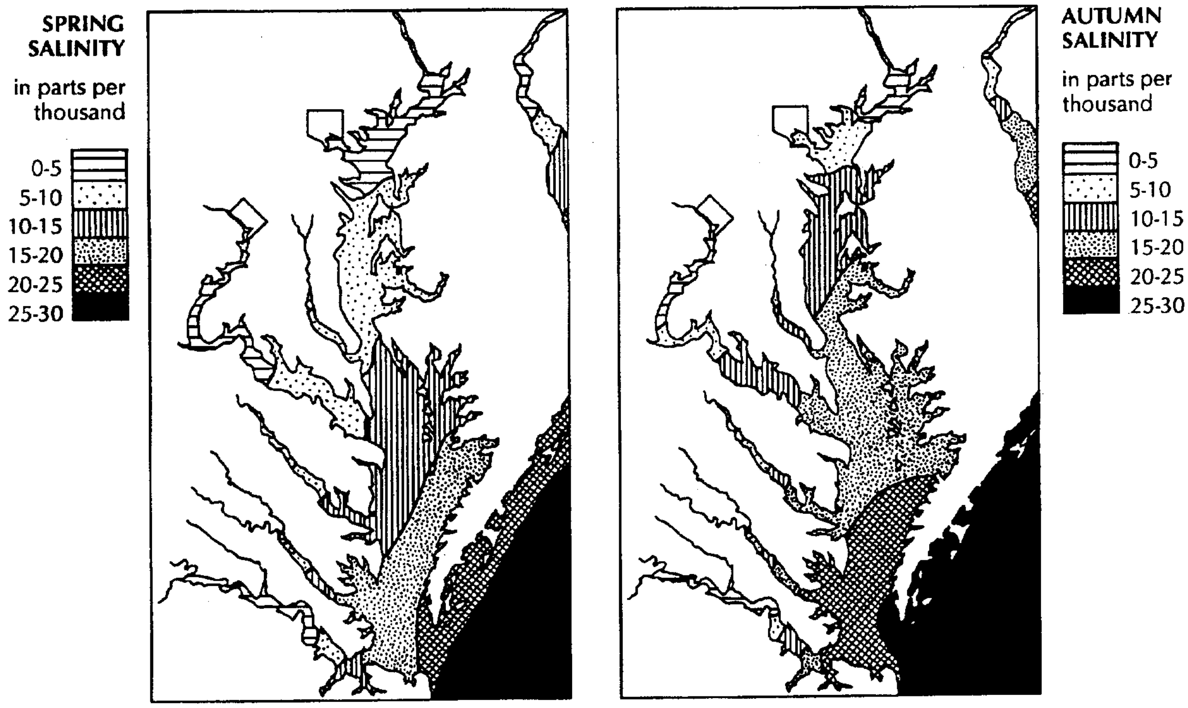

Isohalines mark the salt content of surface water. The salinity gradient varies during the year due to freshwater input: fresher during spring rains, saltier during the drier months of autumn.

Seawater from the Atlantic Ocean enters the mouth of the Bay. Salinity is highest at that point and gradually decreases as one moves north. Salinity levels within the Chesapeake vary widely; both seasonally and from year to year, depending on the volume of freshwater flowing into the Bay. On a map, isohalines or salinity contours mark the salt content of surface waters. Because the greatest volume of freshwater enters the Bay from northern and western tributaries, isohalines tend to show a southwest to northeast tilt. The rotation of the earth also drives this salinity gradient. Known as the Coriolis force, it deflects flowing water to the right in the Northern Hemisphere so that saltier water moving up the Bay is deflected towards the Eastern Shore.

Temperature dramatically changes the rate of chemical and biological reactions within the water. Because the Bay is so shallow, its capacity to store heat over time is relatively small. As a result, water temperature fluctuates throughout the year, ranging from 0-29 C° (32-84 F°). These changes in water temperature influence when plants and animals feed, reproduce, move locally or migrate. The temperature profile of the Bay is fairly predictable. During spring and summer, surface and shallow waters are warmer than deeper waters with the coldest water found at the bottom. Often turbulence of the water helps to break down this layering.

Just as circulation moves much needed blood throughout the human body, circulation of water transports plankton, fish eggs, shellfish larvae, sediments,

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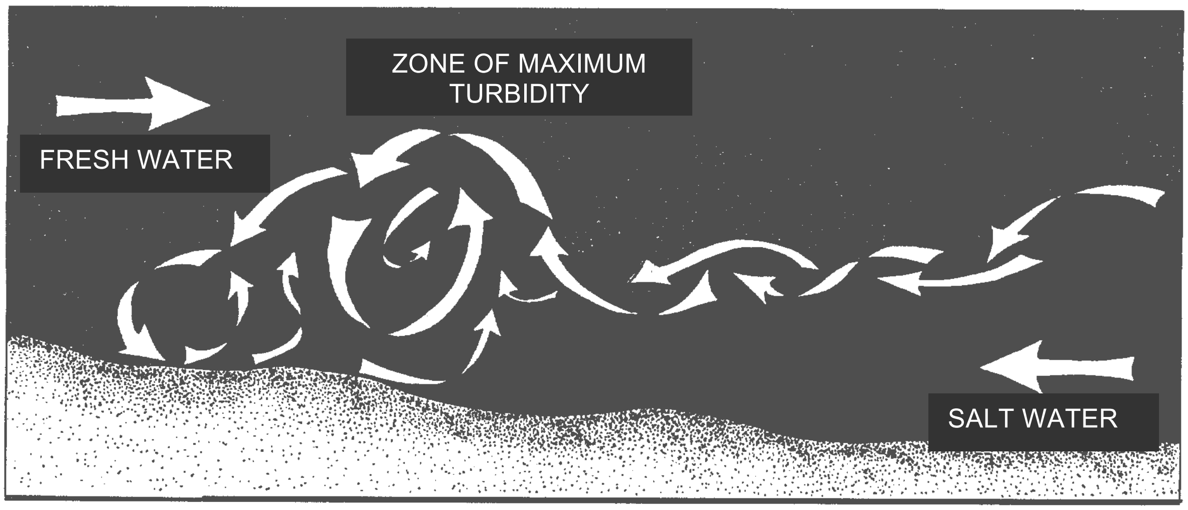
dissolved oxygen, minerals and nutrients throughout the Bay. Circulation is driven, primarily, by the movements of freshwater from the north and salt water from the south. Circulation causes nutrients and sediments to be mixed and resuspended. This mixing creates a zone of maximum turbidity that, due to the amount of available nutrients, is often used as a nursery area for fish and other organisms.

BAY QUOTE: "...the tide is also governed by the wiind. Southeast makes the highest flood and the northwest and the lowest ebb." Rev. Hugh Jones, 1697



Fresh Water/Salt Water - Zone of Maximum Turbidity

Weather often disrupts or reinforces this two-layered flow. Wind plays a role in the mixing of the Bay's waters. Wind can also raise or lower the level of surface waters and occasionally reverse the direction of flow. Strong northwest winds, associated with high pressure areas, push water away from the Atlantic Coast, creating exceptionally low tides. Strong northeast winds, associated with low pressure areas, produce exceptionally high tides.

Together, salinity, temperature and circulation dictate the physical characteristics of water. The warmer, lighter freshwater flows seaward over a layer of saltier and denser water flowing upstream. The opposing movement of these two flows forms saltwater fronts or gradients that move up and down the Bay in response to the input of freshwater. These fronts are characterized by intensive mixing. A layer separating water of different densities, known as a pycnocline, is formed. This stratification varies within any season depending on rainfall. Stratification is usually highest in the spring as the amount of freshwater in the Bay increases due to melting snow and frequent rain. Stratification is maintained throughout summer due to warming of surface waters.

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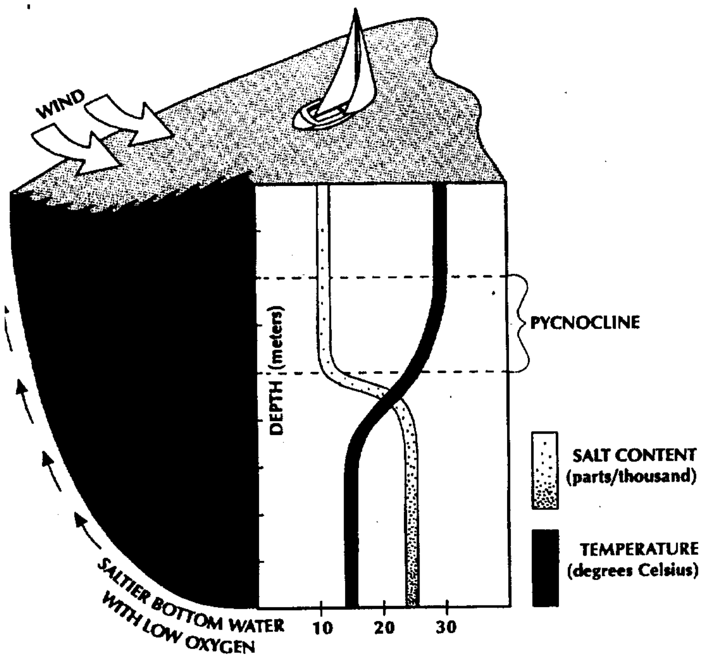

The change in temperature and salinity divides the Bay into saltier bottom water and lighter, fresher surface water. A blurry, mixing layer, known as the pycnocline, divides the two. Strong winds can pile surface water against one shore of the Bay. To reestablish equilibrium, the bottom layer flows up into shallower water.

In autumn, fresher surface waters cool faster than deeper waters and sink. Vertical mixing of the two water layers occurs rapidly, usually overnight. This mixing moves nutrients up from the bottom sediments, making them available to phytoplankton and other organisms inhabiting upper water levels. This turnover also distributes much-needed dissolved oxygen to deeper waters. During the winter, water temperature and salinity are relatively constant from surface to bottom.

• Suspended Sediments: Composition and Effects

The waters of the Chesapeake and its tributaries transport huge quantities of sediments. Although sediments are a natural part of the Bay ecosystem, accumulation of excessive amounts of sediments is undesirable. Accumulation of sediments can fill in ports and waterways.

This sedimentation process has already caused several colonial seaports, like Port Tobacco, Maryland, to become landlocked. As they settle to the bottom of the Bay, the sediments can also smother the bottom dwelling plants and animals. Sediments suspended in the water column cause the water to become cloudy, or turbid, decreasing the light available for SAV growth.

Sediments can also carry high concentrations of certain toxic materials. Individual sediment particles have a large surface area, and many molecules easily adsorb, or attach, to them. As a result, sediments can act as chemical sinks by adsorbing metals, nutrients, oil, pesticides and other potentially toxic materials. Thus, areas of high sediment deposition sometimes have high concentrations of nutrients, persistent (long-lasting) chemicals and contaminants, which may later be released.

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In the upper Bay and tributaries, sediments are fine-grained silts and clays that are light and can be carried long distances. These sediments are carried by the fresh, upper layer of water. As they move into the Bay, the particles slowly descend into the denser saline layer. Here, the particles may reverse direction and flow back up toward tidal tributaries with the lower layer of water. As the upstream flow decreases, the sediments settle to the bottom.

Sediments in the middle Bay are mostly made of silts and clays. These sediments are mainly derived from shoreline erosion. In the lower Bay, by contrast, the sediments are sandier, and heavier. These particles result from shore erosion and inputs from the ocean. Sediments drop to the bottom fairly rapidly, remain near their original source and are less likely to be resuspended than finer silts.

• Chemical Make-up

Like temperature and salinity, the chemical composition of the water also helps determine the distribution and abundance of plant and animal life within the Bay. The waters of the Chesapeake contain organic and inorganic materials, including dissolved gases, nutrients, inorganic salts, trace elements, heavy metals and potentially toxic chemicals.

The more saline waters are chemically similar to seawater. Major constituents include chlorides, sodium, magnesium, calcium and potassium. Dissolved salts are important to the life cycles of many organisms. Some fish spawn in fresh or slightly brackish water and must move to more saline waters as they mature. These species have internal mechanisms that enable them to cope with the changes in salinity.

BAY FACT: Due to a lack of oxygen in the water, hundreds of blue crabs may run out onto land. This rare phenomena is known as a "crab jubilee".

Seawater also contains hundreds of trace elements that are important in many biological reactions. For example, living organisms require minute quantities of cobalt to make vitamin B-12 . Metals, such as mercury, lead, chromium and cadmium, also occur in low concentrations.

The composition of seawater is relatively constant from place to place. Freshwater, however, varies depending upon the soil and rocks the water has come in contact with. Both fresh and saltwater contain a myriad of natural dissolved materials. These come from several sources. Microorganisms, such as bacteria, decompose dead organisms and release compounds into the water. Live organisms also release compounds directly into the water. In addition, dissolved material enters into the Bay via its tributaries and the ocean.

Dissolved oxygen is essential for most animals inhabiting the Bay. The amount of available oxygen is affected by salinity and temperature. Cold water can hold more dissolved oxygen than warmer water and freshwater holds more

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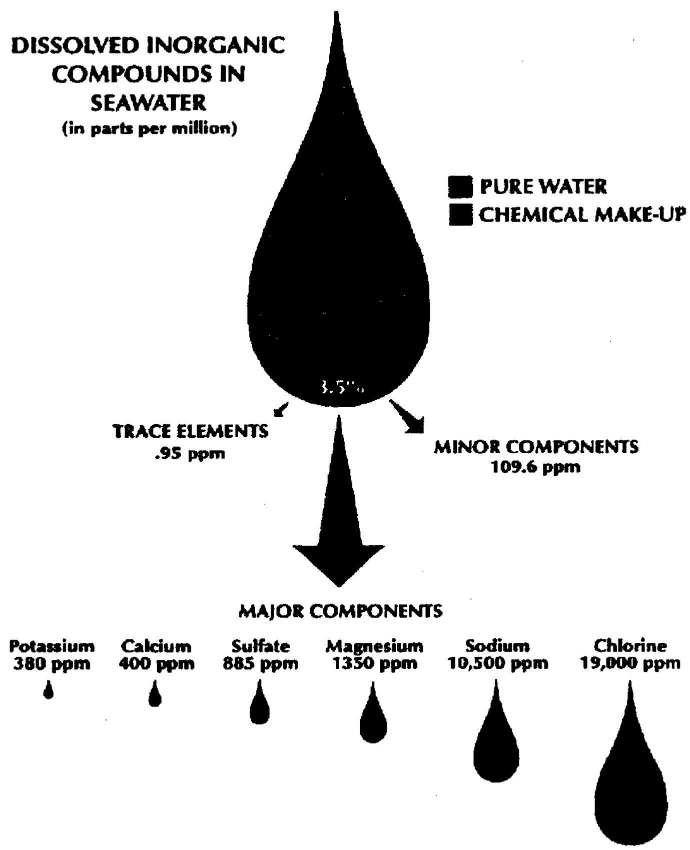
than saline water. Thus, concentrations of dissolved oxygen vary, in part, with both location and time. Oxygen is transferred from the atmosphere into the surface waters by diffusion and the aerating action of the wind. It is also added as a by-product of photosynthesis. Floating and rooted aquatic plants and phytoplankton release oxygen when photosynthesizing. Since photosynthesis requires light, production of oxygen by aquatic plants is limited to shallow water areas, usually less than 2 meters (approximately 6 feet) deep. Surface water is nearly saturated with oxygen most of the year, while deep bottom waters range from saturated to anoxic (no oxygen present).



Dissolved Inorganic Compounds in Seawater
(in parts per million)

During the winter, respiration levels of organisms are relatively low. Vertical mixing is good and there is little salinity or temperature stratification. As a result, dissolved oxygen is plentiful throughout the water column. During the spring and summer, increased levels of animal and microbial respiration and greater stratification may reduce vertical mixing, resulting in low levels of dissolved oxygen in deep water. In fact, deep parts of some tributaries like the Patuxent, Potomac and Rappahannock rivers and deep waters of the Bay's mainstem can become anoxic in summer. In the autumn, when surface waters cool, vertical mixing occurs and deep waters are re-oxygenated.

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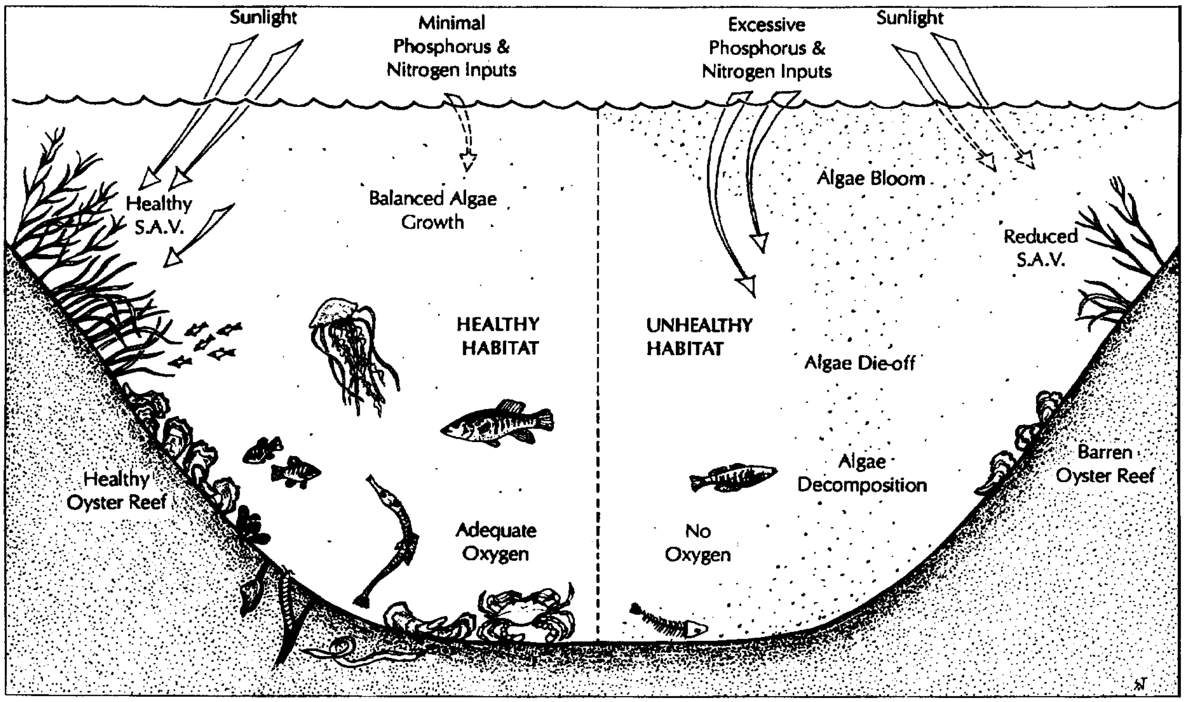
Carbon dioxide, another dissolved gas, is important to the well-being of the Bay's aquatic environment. It provides the carbon that plants use to produce new tissue during photosynthesis, and is a by-product of respiration. Carbon dioxide is more soluble in water than oxygen. Its availability is also affected by temperature and salinity in much the same fashion as oxygen.

Nitrogen is essential to the production of plant and animal tissue. It is used primarily by plants and animals to synthesize protein. Nitrogen enters the ecosystem in several chemical forms and also occurs in other dissolved or particulate forms, such as in the tissues of living and dead organisms.



Healthy Habitat and Unhealthy Habitat

Some bacteria and blue-green algae can extract nitrogen gas from the atmosphere and transform it into organic nitrogen compounds. This process, called nitrogen fixation, cycles nitrogen between organic and inorganic components. Other bacteria release nitrogen gas back into the atmosphere as part of their normal metabolism in a process called denitrification. Denitrification removes about 25 percent of the nitrogen entering the Bay each year.

Phosphorus is another key nutrient in the Bay's ecosystem. In the water, phosphorus occurs in dissolved organic and inorganic forms, often attached to particles of sediment. This nutrient is essential to cellular growth and reproduction. Phytoplankton and bacteria assimilate and use phosphorus in their growth cycles. Phosphates, the organic form are preferred, but organisms will use other forms of phosphorus when phosphates are unavailable.

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In the presence of oxygen, high concentrations of phosphates in the water will combine with suspended particles. These particles eventually settle to the Bay bottom and are temporarily removed from the cycling process. Phosphates often become long-term constituents of the bottom sediments. Phosphorus compounds in the Bay generally occur in greater concentrations in less saline areas, such as the upper part of the Bay and tributaries. Overall, phosphorus concentrations vary more in the summer than winter.

BAY FACT: During the 1600s, wolves, cougars, elk and buffalo still inhabited the Chesapeake Bay watershed.

Nutrients, like nitrogen and phosphorus, occur naturally in water, soil and air. Just as the nitrogen and phosphorus in fertilizer aids in the growth of agricultural crops, both nutrients are vital to the growth of plants within the Bay. Excess nutrients, however, are pollutants. Sewage treatment plants, industries, vehicle exhaust, acid rain, and runoff from agricultural, residential and urban areas are additional sources of nutrients entering the Bay.

Excess amounts of phosphorus and nitrogen cause rapid growth of phytoplankton, creating dense populations, or blooms. These blooms become so dense that they reduce the amount of sunlight available to submerged aquatic vegetation. Without sufficient light, plants cannot photosynthesize and produce the food they need to survive. Algae may also grow directly on the surface of SAV, blocking light. Another hazard of nutrient-enriched algal blooms that are not consumed by zooplankton comes after the algae die. As the blooms decay, oxygen is used up in decomposition. This can lead to dangerously low oxygen levels that can harm or even kill aquatic organisms.

Besides nutrients, people add other substances to the Bay's water creating serious pollution problems. Heavy metals, insecticides, herbicides and a variety of synthetic products and by-products can be toxic to living resources. These contaminants reach the Bay through municipal and industrial wastewater, runoff from agricultural, urban and industrialized areas and atmospheric deposition.

This situation is improving. In some cases, industrial wastewater is pretreated to remove contaminants. The use of especially damaging synthetic substances, like DDT and Kepone, has been banned.

In an effort to control nutrient pollution, the states of Maryland, Pennsylvania and Virginia and the District of Columbia agreed to reduce the total amount of nutrients entering the Bay by 40 percent by the year 2000. Controllable sources include runoff from agricultural, suburban and urban areas, wastewater treatment plants, and industry. A ban on laundry detergents containing phosphates has reduced phosphorus levels. New technologies implemented at many sewage treatment plants remove phosphorus and some nitrogen before the effluent is discharged into rivers. Other efforts include maintaining forested or other vegetated buffer strips along water sources, reducing fertilizer use on farms and lawns and managing animal waste.

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