UNDERSTANDING SALTWATER INTRUSION
AND GROUND WATER QUALITY

Introduction
Saltwater intrusion is the movement of saline water into regions of an aquifer previously occupied by fresher and less saline ground water and can be the result of natural hydrologic processes or dramatically enhanced by pumping ground water (SWFWMD, 2003). Saltwater intrusion is a potential threat to the quality of ground water for both inland and coastal areas. In many coastal areas in Florida, increased chloride concentrations in ground water up to 14 miles inland indicate that saline water is gradually intruding into the freshwater zones of the Floridan aquifer system (Spechler, 2000).

Saltwater is more dense than fresh water and exerts a constant pressure toward freshwater zones. As long as fresh water levels in the aquifer are above sea level, the pressure from the fresh water limits the inland movement of the salt. The problem of saltwater intrusion is aggravated by periods of drought during which there is not enough rainfall to replenish the fresh water aquifers. When fresh water levels are decreased by drought, the transition zone where fresh and saltwater meet rises and degrades the fresh water aquifer. Overpumping of coastal wells can also increase saltwater intrusion. When ground water is pumped from the freshwater aquifers above the saline zone faster than it can be replenished, upward or lateral movement of saline water toward the pumped well(s) occurs.

The potential for saltwater intrusion is higher where population increases necessitate increased ground water pumping, resulting in a decline in the potentiometric surface of the aquifer system. Other changes such as climate and drought conditions can further stress the available ground water supply of fresh water. Once freshwater aquifers are impacted by saltwater intrusion, restoration of the aquifer system is difficult, costly and may often be impossible. The alternatives to restoration, which include drilling new supply wells or desalinizing ground water before use, are also expensive. However, increasing water demands have encouraged the development of new technologies to desalinize ground water that are now more economically feasible. The use of saline ground water as a source of public supply increased 178 percent between 1985 [17.28 million gallons per day (MGD)] and 1990 [47.56 MGD] (Bergquist, 2003).

Modern Seawater-Freshwater Interface
The lateral and vertical extent of the seawater-freshwater interface differs between unconfined and confined aquifers (Figure S1) (SWFWMD, 2003). Pumping near the saltwater-freshwater interface can result in a lower head and an increased potential for lateral movement of saline water. If seawater is moving laterally through the Upper Floridan aquifer, the saltwater is first detected in wells nearest the coast with subsequent landward movement of the freshwater-saltwater interface.
The seawater/freshwater interface near coastal areas is the zone where the TDS concentration is 500 mg/L or greater and the chloride concentration is 500 mg/L or greater (Figure S2) (Sofia, 2003).
Reclit Saltwater-Freshwater Interface
There is also a saltwater/freshwater interface between the freshwater upper Floridan and the more saline lower Floridan aquifers, with higher salinity due to trapped ancient seawater. Pumping from the shallower freshwater zones of the aquifer can result in a reduced pressure head and an increased potential for upward movement of saline water through nearly vertical zones of preferential permeability (Figure S3) (Barlow and Wild, 2002). Structural anomalies can create zones of relatively high vertical hydraulic conductivity, thereby providing a hydraulic connection between freshwater zones and deeper, more saline zones. Saline water entering the freshwater zones can mix and move through the porous matrix of the aquifer or along horizontal fractures or solution zones.

The first step in slowing the rate of movement of the saltwater-freshwater interface is to stabilize the regional ground water levels. This involves ensuring that the amount of pumping and water use does not exceed the available ground water supply and levels in the aquifers. Section 373.042(3), Florida Statutes, (1996 supp.) requires water management districts to establish minimum water levels in priority areas that are protective against regional saltwater intrusion. The North West Florida WMD designates areas as Water Resource Caution Areas if they are expected to experience significant or widespread reductions in water levels, saltwater intrusion or other degradation within the next 20 years. The minimum aquifer level is established as a single value, representing the average potentiometric surface over the area of interest. Telogia Creek is the only WRCA in the basin.

Saltwater Intrusion Indicators
Parameters used as indicators for saline waters mixing with fresh water in aquifers include chloride ($\text{Cl}^{-1}$), sodium ($\text{Na}^{+1}$), sulfate ($\text{SO}_4^{2-}$), specific conductivity (SC), temperature, and total dissolved solids (TDS). Concentrations of these saltwater intrusion indicator analytes are very
different for fresh and saline waters. **Fresh water** typically has a chloride ion concentration of less than 40 mg/L, TDS of 0-1000 mg/L, and a specific conductivity of 50-500 µS/cm. **Sea water** is mainly comprised of chloride (19,000 mg/L) and sodium (10,500 mg/L) (Figure S4).

Chloride and TDS are the most commonly used indicators of seawater intrusion into fresh ground water. When chloride levels are low (less than 50 mg/L), there is little seawater mixing. Sulfate is another indicator, used to identify the intrusion of relict seawater from deep mineralized aquifers. Sulfate can have varying concentrations vertically and laterally and a range from less than 0.2 to 3,000 mg/L. The typical statewide characteristics of the salinity zones and aquifers are discussed further in a later section of this document and are shown in Table S3.

![Figure S4](image.png)

The **Upper Floridan aquifer**’s TDS levels are stabilized to less than 500 mg/L by saturation with calcite and dolomite, and smaller amounts of dissolved iron, manganese, nitrate, phosphate, fluoride, strontium, sulfide, and silica depending on local occurrence. Within the Upper Floridan aquifer, the dominant cations are Ca, Mg, Na, and K and the dominant anions are HCO₃, Cl, and SO₄. In the Upper Floridan, dissolved-solids concentrations vary from less than 25 mg/L near outcrop areas to more than 25,000 mg/L along the coasts (Sofia, 2003).

The **Lower Floridan aquifer** has a TDS level of more than 100 times that of the Upper Floridan and is commonly 48,000 mg/L or higher. The water type of the **Lower Floridan aquifer** is similar to seawater and is sodium and chloride rich with typical chloride concentrations of 5,000 mg/L at the top and 19,000 mg/L at the base (Reese and Memberg, 2000). However, the ground water originating from the lower Floridan aquifer can have high sulfate concentrations (commonly 1500-3000 mg/L in inland areas) with low chloride concentrations (25 mg/L or less). Therefore, sulfate is an important inclusion in the saltwater intrusion indicator parameters.
Determining the origin of elevated salinity can be complex since changes in chloride, sodium and total dissolved solids could be due to modern seawater advancing landward or relict seawater leaking upward from lower mineralized aquifers. The range of typical values from a number of researchers has been compiled to interpret saltwater intrusion data (Table S1). The chemical and isotopic (hydrogen, oxygen and strontium) composition of ground water has also been used by USGS to investigate the origin of salinity, but this is difficult when data suggests the ground water is a mixture of freshwater recharge, upward leakage and modern seawater (Schmerge, 2001).

If saltwater intrusion is due to upwelling from deeper ground water, then sulfate and chloride concentrations would be expected to increase rapidly with depth. Sulfate in ground water is generally lowest inland, particularly where the Floridan aquifer is unconfined and/or near the surface, and highest in the deeper confined Floridan aquifer system. Sulfate enriched ground water (>100 mg/L) occurs as a natural occurrence primarily where there is dissolution of evaporite minerals (gypsum and anhydrite), which are found at the base of the Upper Floridan aquifer, or in the underlying middle confining unit and Lower Floridan aquifer (Sacks, 1995).

### TABLE S1. STATEWIDE CHARACTERISTICS OF SALINITY ZONES AND AQUIFERS

<table>
<thead>
<tr>
<th>SALINITY AND AQUIFERS</th>
<th>Altitude (fmsl)</th>
<th>Total Dissolved Solids (mg/L)</th>
<th>Chloride (mg/L)</th>
<th>Specific Conductance (µS/cm)</th>
<th>Sodium (mg/L)</th>
<th>Sulfate (mg/L)</th>
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<tbody>
<tr>
<td><strong>Freshwater</strong></td>
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<td></td>
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<td></td>
<td></td>
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<tr>
<td>Surficial and Upper Floridan</td>
<td>0-2064</td>
<td>172-289</td>
<td>5-26</td>
<td>50-500</td>
<td>5</td>
<td>0.2-100</td>
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<td></td>
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<tr>
<td>Upper Floridan</td>
<td>2064-2176</td>
<td>1360-4330</td>
<td>190-1300</td>
<td>2500-25000</td>
<td>1-1300</td>
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<tr>
<td>Mid-Confining Unit</td>
<td>2176-2675</td>
<td>33600</td>
<td>18000</td>
<td>35000-37000</td>
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<td><strong>Brine</strong></td>
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<td>26000</td>
<td>43000-50000</td>
<td>1500-3000</td>
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<td>10760</td>
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BIBLIOGRAPHY


