

AQUIFER CHANNELIZATION

3. INCREASING AQUIFER INJECTIONS

Additional Expenditures and Adverse Impacts to Implement ASR in the Everglades

Despite the documented poor results for attempted "recovery" of injected fluids intended to be "stored" in the aquifer for later use, the Corps has proposed to fund the construction/operation of up to seven wells in the Everglades watershed, for "ASR pilot projects" under CERP. Following the release of the USGS report in 2002, revealing that actual "recovery" for only two of the 87 cycle tests for the ASR wells in the Everglades watershed exceeded 15%, and prior to the conclusion of the final EIS to evaluate the use of ASR in the Everglades (in September 2004), the Corps proceeded with plans to construct/operate ASR facilities in the Everglades.

In October 2003, the engineering firm CH2M Hill submitted a report to the Corps for ASR wells at "Pilot Project Surface Facilities Design for Lake Okeechobee and Hillsboro Canal Sites." As indicated previously, actual "recovery" for the three ASR cycle tests conducted by USGS at the Lake Okeechobee site was 0% after 0, 5, and 8 days of "storage." The controversial Hillsboro Canal site in Palm Beach County reportedly was being constructed prior to the release of the USGS report (see Table 1 from [Reese, 2002](#)).

The CH2M Hill report (preceded by three pages of errata corrections) was included in Appendix D of the final EIS (US Army Corps of Engineers, 2004a). In the transmittal letter from Joel Hall (CH2M Hill Project Manager) to the Corps, the following [four ASR sites](#) in the Everglades and associated injection volumes were identified: Kissimmee River Site (5 Mgd); Port Mayaca Site (10 Mgd); Moore Haven Site (5 Mgd); and Hillsboro Canal Site (5 Mgd).

Intended addition of harmful and toxic chemicals

The addition of chloramine (chlorine and ammonia) was identified for intended use in water treatment at the Port Mayaca and Moore Haven ASR Sites. As much as 4 mg/L of sulfuric acid also would be added to the water to "adjust" the pH to 4.5. Both chlorine and ammonia are highly toxic to aquatic and marine organisms. Additionally, those additives include nitrogen, which increases nutrient loading to an ecosystem already crippled by excessive nutrient loads. Loading rates were identified by CH2M Hill as 1-5 mg/L chloramine residual (US Army Corps of Engineers, 2004a, Appendix D, pp. 37 and 58).

These toxic compounds are added to the ASR water for disinfection as sodium hypochlorite (chlorine) and liquid ammonia (aqua ammonia or ammonium sulfate), according to the CH2M Hill report. The chemicals are added at the "discharge side of the product transfer pumps" (US Army Corps of Engineers, 2004a, Appendix D, p. 38).

The single paragraph in the CH2M Hill report to the Corps that addresses "Environmental Impacts" identifies five sub-criteria: visual, traffic, noise, lighting, and chemicals. The following justification is included in that paragraph (US Army Corps of Engineers, 2004a, Appendix D, p. 5):

... Passive processes with minimal mechanical requirements will have the least impact. Processes that include significant structures, chemical storage, residuals management, and operator attention will have the highest environmental impact.

...

It is important to note that restoration of natural overland flow (sheet flow) through the

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Everglades is a passive process. The proposed transport of hundreds of millions of gallons of water daily to and from ~330 ASR well locations throughout the Everglades watershed - to be injected and withdrawn, treated and transported to users - is a process that includes significant structures, chemicals, and management.

Inadvertent addition of harmful and toxic chemicals

In addition to adverse impacts to wetlands and other surface waters from ASR-related hydroperiod alterations and deliberate addition of harmful and toxic chemicals, inadvertent additions of harmful and toxic chemicals also occur as subsurface discharges to surface waters. Injected fluids are known to enter surface waters in southern Florida as subsurface discharges from the aquifer (summarized in [Bacchus, 2001](#); 2002). All sources of chemical alterations can result in dire adverse impacts to the ecosystem, despite the failure of the Corps' final EIS to address these impacts. Adverse environmental impacts to coastal waters from these types of submarine groundwater discharges (SGD) are described by [Bacchus \(2001\)](#).

Contaminants in injected stormwater – One source of water for ASR injection is stormwater runoff. Stormwater runoff contains myriad urban, industrial and agricultural contaminants harmful or toxic to marine and aquatic organisms. Heavy metal contaminants (*e.g.*, chromium and lead) are among the harmful and toxic contaminants known to occur in stormwater runoff. Motor vehicle operation is a source of chromium in urban stormwater runoff. [Campbell \(1995\)](#) evaluated fish exposed to urban stormwater runoff in Florida. She found those fish had chromium concentrations within the range of values in fish collected from other contaminated sites, but higher than values in fish from uncontaminated reference sites. Her research also suggested biomagnification of chromium in higher levels of the food chain.

Experiments with clams placed in streams receiving urban and industrial stormwater runoff or free from those pollutants also have been conducted in the geographic vicinity of the Everglades. Observations on the clams were made after exposure to stream water for 2 to 10 weeks. Although no significant differences were observed in growth rates in clams from the contaminated and noncontaminated streams, DNA strand lengths in clams from contaminated streams were significantly shorter than DNA strand lengths in clams from the uncontaminated stream after stream exposures of only 4 weeks. Those results suggest a reduction in DNA integrity and possible presence of genotoxic chemicals in the contaminated stormwater runoff. Other differences detected in the *in-situ* experiment included significantly lower percentage of water in tissue of clams exposed to stormwater runoff, suggesting that tissue hydration is a more sensitive indicator of sublethal toxicity than growth (Black and Belin, 1998).

Most recently lethality and genotoxicity experiments have been conducted by exposing mussels to chemicals applied to golf course turf and lawns. Many chemicals, including fertilizers, herbicides and insecticides routinely are applied to golf course turf and lawns. The chemicals tested, singly and in combination (24-hour exposures), included copper and commercial formulations of atrazine, glyphosate, carbaryl, and diazinon. The organisms used in these experiments (mussels (*Utterbackia imbecillis*) in early life stage) had chemical sensitivities similar to or greater than other aquatic organisms commonly used in toxicity tests (Connors and Black, 2004).

In the acute toxicity tests during those experiments copper was the most toxic of all chemicals evaluated, with the lethal concentration for 50% of the organisms only 37.4 µg/L. Carbaryl was the most toxic of all pesticides evaluated with a similar lethal dose of 7.9 mg/L. The combined toxicity of equitoxic and environmentally realistic mixtures was additive.

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Genotoxic responses were observed following exposures to copper, atrazine and diazinon at levels below their respective no-observed-effect concentrations (Connors and Black, 2004).

The acute and chronic toxicity and genotoxicity (*e.g.*, DNA breakage) findings described in this section associated with stormwater runoff (above) and sewage effluent (below) are not comprehensive. The results of the referenced studies merely represent some of the documented serious adverse impacts to non-target surfacewater organisms. An additional critical consideration involves constructed wetlands commonly used to "treat" urban, industrial and agricultural stormwater runoff and in some cases municipal sewage effluent. Residual toxicity of contaminants in final discharges from these wetlands has been documented, however, verifying the need for more extensive pre- and posttreatment prior to discharge of these fluids to surface waters (Belin *et al.*, 2000), including via subsurface discharges.

Contaminants in injected treated sewage effluent – Treated sewage effluent ("reuse" water) includes myriad urban, industrial and agricultural contaminants that are harmful or toxic to marine and aquatic, including many of the same contaminants found in contaminated stormwater runoff. Pharmaceuticals are one of many types of additional contaminants in treated sewage effluent, including advanced-treated wastewater (AWT). Many of the prescription drugs that humans consume are excreted, with limited retention, in feces and urine, with increasing concentrations contained in sewage effluent. Prozac, for example, is a commonly prescribed antidepressant drug found in treated effluent. The increasing presence of Prozac in surface waters receiving treated effluent is causing concerns over the effects of these pharmaceutical products on wildlife. Recent laboratory experiments by Black and Armbrust exposed frog tadpoles and fish to water with low concentrations of these medications. Results revealed that these low concentrations slowed rates of development and caused sluggish behavior that would increase vulnerability to predators and ultimately disrupt ecological biodiversity (<http://www.researchmagazine.uga.edu/summer2005/prozac01.htm>).

Prozac is only one of numerous selective serotonin reuptake inhibitors (SSRI) discharged to surface waters through sewage effluent. These SSRIs are among the 200 most-prescribed medications in the United States and have been detected in low concentrations in surface waters receiving treated sewage. Because low concentrations of these compounds can affect both the nervous and endocrine systems (endocrine disruptors), the detection of these compounds in surface waters causes great concern regarding the potential negative effects on organisms exposed to those waters (Henry *et al.*, 2004).

Five SSRIs (fluoxetine, Prozac®; fluvoxamine, Luvox®; paroxetine, Paxil®; citalopram, Celexa®; and sertraline, Zoloft®) recently were tested for acute and chronic environmental toxicity under controlled laboratory conditions using a small commonly occurring aquatic organism (*Ceriodaphnia dubia*). The lethal dose for the organisms exposed to these SSRIs after only 48 hours (acute toxicity) ranged from 0.12 to 3.90 mg/L. The order of toxicity for these compounds was (lowest to highest): Citalopram, fluvoxamine, paroxetine, fluoxetine, sertraline. Mortality data for the 8-day chronic toxicity tests were similar to acute toxicity results. Exposure of the test organisms to those SSRIs also resulted in negative effects on reproduction by reducing the both the number of young per brood and the number of broods, but only at SSRI concentrations higher than concentrations expected in surface waters. For sertraline, the most toxic SSRI, the lowest-observable-effect concentration for reduction of survival and reproductive success was 0.045 mg/L and the no-observable-effect concentration was 0.009 mg/L (Henry *et al.*, 2004).

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Black and McCarthy (1990) have summarized the sources of chlorine discharges to surface waters. Chlorine is another common industrial disinfectant used in municipal water supplies and resulting in pulsed surfacewater discharges of relatively high concentrations (0.5 mg/L). Lower concentrations of chlorine are found in industrial effluent and domestic sewage effluent. Fish exposed to chlorine exhibit typical physiological and pathological (gills and respiration) responses, including secretion of mucus and coughing reflex. Chlorine is acutely toxic to freshwater fish.

Early experiments examining the effect of sublethal chlorine (0.04 mg/L) exposure on freshwater fish for 24 hours resulted in chlorine-induced changes in fish gill histopathology and respiration, including proliferation of mucous cells. The types of pathological changes observed were expected to decrease functional gill surface area in fish exposed to chlorine in the absence of increased ventilation to compensate for lowered oxygen uptake efficiencies (Black and McCarthy, 1990). Aquifer injection of treated sewage effluent in southern Florida occurs without chlorine removal (Bacchus, unpublished data).

Mobilized and displaced contaminants – The mechanisms for karst aquifer (*e.g.*, conduit) flow were described in Chapter 2. Those mechanisms are responsible for the inevitable co-mingling of injected fluids with and displacement of groundwater contaminants present prior to ASR injections and the ultimate subsurface discharges of those contaminants to surface waters. Examples of sources of groundwater contaminants that ASR injections can displace or co-mingle with include golf courses, agricultural fields, commercial and residential lawns, sewage sludge disposal sites and septic tank discharge. The sections above and below provide examples of the types of contaminants present in these sources.

Other contaminants - such as arsenic - are bound in the aquifer formations. Those bound contaminants are released into the ground water as a result of ASR injections. Once released into the ground water, subsequent injections of any fluids can displace these contaminants and result in discharges to surface waters. The increasing problem with arsenic contamination associated with ASR injections is discussed in more detail in Chapter 4.

Cumulative impacts of additional toxic chemicals

Chronic illnesses/death of marine life and harmful algal blooms - The regulatory agencies have been unable (or unwilling) to explain the chronic illnesses of marine life, the harmful algal blooms, the fish kills and the marine mammal deaths which have increased in frequency, duration and intensity in coastal areas located in proximity to areas of aquifer injection along Florida's coast. These unexplained occurrences include sea turtles with tumor-like growths and dolphins with ulcers, lesions, and malignant lymphoma. For example, research by Harbor Branch Oceanographic Institute has estimated that 40% of dolphins found in the Indian River Lagoon have skin diseases ranging from dolphin pox to fungal diseases. Although cancer is rare in marine mammals, malignant lymphoma has been documented in dolphins from this area for the past 10 years (St. Johns River Water Management District, 2004b, <http://www.sjrwmd.com/programs/outreach/pubs/index.html>).

No effort has been made to evaluate the cumulative adverse impacts that the additional aquifer injections - being proposed as ASR - would have on publically unexplained maladies in the marine life in southern Florida, such as those documented in the Indian River Lagoon and southern Gulf Coast. For example, ASR injections mobilize arsenic bound in the aquifer formations (see Chapters 2 and 4) and other contaminants presently associated with the regional

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aquifer system, ultimately causing the subsurface discharge of these contaminants.

Sewage sludge ("biosolids") - In addition to sewage effluent (the liquid component) sewage sludge ("biosolids") is a second harmful and toxic component of conventional sewage treatment plants (STPs), also known as wastewater treatment plants (WWTPs). Sewage sludge contains high concentrations of nutrients and organic matter in addition to heavy metals and synthetic organic chemicals. The approved disposal method for sewage sludge is land application. The toxicants in sewage sludge can enter surface waters as surface discharges from stormwater runoff and as subsurface discharges of contaminants leached into the ground water at the land application sites (Konwick *et al.*, 2003).

Both pathways for surfacewater discharges of sewage sludge contaminants from land application sites in the Everglades watershed (and throughout Florida) represent cumulative impacts to ASR aquifer injections. As indicated in preceding sections, ASR injections can co-mingle with and displace other contaminants present in ground water in the vicinity of ASR sites.

Results of recent laboratory experiments indicated that elutriates were highly toxic (lethal) to the same aquatic organisms used in the pharmaceutical experiments by Henry *et al.* (2004) described above. Elevated concentrations of 4-nonylphenol (4-NP) were found in several biosolid samples that had high elutriate toxicity (Konwick *et al.*, 2003). Nonylphenol is an endocrine disruptor.

The biosolids toxicity experiments were conducted using elutriates (fluids) from Class B biosolids and composted biosolids (Class A) from six southeastern treatment plants. The tests were conducted to mimic the biosolid/water mixture that would occur during surface runoff or leaching from the soils at biosolid land application sites. Reductions in dissolved oxygen concentrations (commonly associated with high levels of nutrients in water) confounded toxicity results (Konwick *et al.*, 2003).

Based on the results of the biosolids experiments the scientists recommended the use of alternatives to current treatment and disposal methods of biosolids to reduce the potential for toxicants entering surface waters (Konwick *et al.*, 2003). Waterless composting toilets are environmentally sound cost effective alternatives to centralized sewage (wastewater) treatment plants.

Examples of Costs Associated with ASR

Annual costs for the addition of toxic chemicals

The **annual** cost of the "chloramination" (erroneously referenced as "UV System") for the 5 Mgd Moore Haven ASR facility was identified as **\$168,000**, in the CH2M Hill report. The **annual** cost of 'chloramination' at the 10 Mgd Port Mayaca site was not specified, but was presumed to be represented by the **\$862,000** "Chemical Feed System" referenced in the facility budget for that site (US Army Corps of Engineers, 2004a, Appendix D, pp. 45 and 66).

The CH2M Hill budgets for the proposed "ASR pilot projects" were listed as: **\$5,506,000** for the Kissimmee River site; **\$5,594,000** for the Moore Haven site; **\$5,449,000** for the Hillsboro Canal site; and **\$8,041,000** for the Port Mayaca site. The "Markups" for these sites are based on percentages of the total construction costs, which include the cost of adding the toxic chemicals. Therefore, the more expensive the projects are, the greater the payment to the engineering company for "markups." The percentages for "Markups" for each of the ASR sites include: 5% Overhead; 10% Profit; 3% Mobilization/Bonds/Insurance; and 25% Contingency (not specified in the document). The **total CH2M Hill "Markups"** for the Kissimmee River, Moore Haven,

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Hillsboro Canal, and Port Mayaca ASR sites were **\$1,379,000**, **\$1,347,000**, **\$1,327,000**, and **\$1,562,000**, respectively (US Army Corps of Engineers, 2004a, Appendix D, pp. 34, 45, 55, and 66). The **annual** costs at those two proposed "ASR pilot projects" for introducing additional toxic chemicals to the sensitive Everglades ecosystem would be ~\$1 million.

Annual costs to reverse damage from additional nutrient loading/contaminant discharge

The annual costs that will be incurred in the future through attempts to reverse the damage to the Everglades and associated ecosystems from additional nutrient loading and contaminant discharges associated with those ASR projects cannot be presented. No information about those annual costs were provided or addressed in the CH2M Hill report or the Corps' EIS.

Annual costs for operating electrical components of ASR

The annual electrical operating costs for the aquifer injections and withdrawals at the four sites were listed as **\$74,000**, **\$33,500**, **\$121,000**, and **\$116,000** (US Army Corps of Engineers, 2004a, Appendix D, pp. 35, 46, 55, and 67). Although the total **electrical-related operating costs** proposed by CH2M Hill for these four ASR projects" would cost taxpayers **more than \$5.6 million per year**, the EIS did not identify the type or source of energy that would provide power for the injections into, and withdrawals from, the aquifer for these ASR projects.

Based on current energy sources in southern Florida, it is presumed that the energy to be used for these projects will not be from sustainable sources such as solar power. Therefore, these annual electrical operating costs will exceed the projected \$5.6 million annual costs described in the Corps' EIS, due to the additional adverse environmental impacts related to the extraction, production, transportation, and consumption of that energy.

Costs for sustainable alternatives

The costs of mandatory water conservation or restrictions were not provided in the Corps' EIS because that alternative was not considered or evaluated in the EIS. Therefore, they failed to report that no increase for annual energy use or related operating costs would be expected to occur under a mandatory water conservation alternative. Likewise, the decreased pumping associated with decreased water use would be expected to result in a significant reduction of energy use and cost for operating energy, with a concomitant significant savings to the taxpayers. Significant benefits to the Everglades and associated ecosystems also would occur with these unaddressed alternatives.

Costs for reversing damage from ASR injections and withdrawals

Costs for large-scale attempts at environmental restoration/clean-up resulting from the failure of the ASR wells to perform as predicted - unaddressed mobilization, displacement, transport and subsurface discharge of additional toxic compounds and nitrogen into the Everglades; inducing subsidence/collapse resulting in aquifer compaction and/or sinkholes - also were not considered in the EIS. Concerns regarding these costs are not trivial, because extensive problems (*e.g.*, improper well construction, upward flow of injected fluids, and contamination) have resulted from similar underground injections for Class 1 disposal wells.

The federal law regulating aquifer injections prohibits the vertical (upward) movement of injected fluids in an effort to prevent overlying aquifer zones from becoming contaminated and unsuitable for use as a source of potable water. A map dated January 2002 ([Figure 10](#)), identifying Class 1 aquifer injection wells in Florida where uncontrolled vertical movement of

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injected fluids was known or suspected, initially was available on the Florida DEP web site. Subsequently that map was removed from the Florida DEP web site (Cynthia Valencic, Legal Environmental Assistance Foundation, personal communication, 2/2/05).

The table that had accompanied that map is included as [Table 2](#). The table prepared by the Florida DEP did not include the well numbers where vertical movement was verified by the limited monitoring required by permit conditions. Those well numbers (in the order of injection locations listed in [Table 2](#)) are: 6, 50, 54, 51, 46, 42, 14, 63, 45, 28, 79, and 23. Additional wells with probable vertical movement of aquifer-injected wastes included 8, 5, 9, 10, 7, and 25, based on information available in the table and aquifer injection map prepared by the Florida DEP and included as [Figure 1B](#). That map confirms that the majority of wells with know or suspected "migration" of injected wastes are located along southern Florida's coast. It also is important to note that those areas are the locations where the chronic illnesses of marine life, the harmful algal blooms, the fish kills and the marine mammal deaths have increased in frequency, duration and intensity.

Because monitoring of these injection wells is extremely limited spatially and temporally and does not include monitoring of vertical flow and discharge to surface waters, all of the more than 125 Class 1 injection wells could be discharging into surface waters such as coastal waters and the Everglades. For example, the City of Plantation is located west of Ft. Lauderdale, ~6 miles (9.7 km) east of the Everglades Wildlife Management Area. The fact that the fluid wastes injected via their North Region wells that flowed vertically, out of the "confinement" zone, did not contaminate a portion of the overlying aquifer currently used as a source of potable water (USDW) does not mean that those wastes have not discharged into Everglades wetlands or coastal waters.

The only Class 1 injection wells that appear to have been evaluated to any significant extent are the Miami-Dade sewage effluent injection wells south of the Hillsboro Canal site, near the coastal waters of Biscayne Bay. Those wells were evaluated in detail by [McNeill \(2000\)](#), an expert from the University of Miami, who was invited to address the National Academy of Sciences Committee (CROGEE) as they were providing their critique of proposed ASR projects.

The wells evaluated by McNeill were constructed and evaluated initially by CH2M Hill. Based on their calculations, CH2M Hill reported that it would take 343 years for vertical upward movement of the injected effluent to reach the base of the upper Floridan aquifer. Sewage effluent injections were initiated at that site in February 1983. The presence of ammonia - a toxic component of sewage effluent - initially was reported in monitoring wells at that site in May 1994, considerably earlier than the 343 years after initial injections predicted by CH2M Hill ([McNeill, 2000](#)).