AQUIFER STORAGE AND RECOVERY: ISSUES FOR SOUTH FLORIDA'S LONG TERM WATER SUPPLIES

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INTRODUCTION

Is Aquifer Storage and Recovery (ASR) the panacea to solve south Florida's water supply problems as indicated in the South Florida Water Management District's Lower East Coast Water Supply Plan, and the United States Army Corps of Engineers' Central and South Florida Restudy? This question has created great trepidation among public utility operators as a result of the proposal to pump over 1.6 billion gallons per day of water into the Floridan Aquifer System, to be recovered later, in an effort to improve South Florida's water supplies in the next 50 years. While several Aquifer Storage and Recovery efforts have proven to be successful in the State of Florida, these efforts have yet to show that large quantities of water can be successfully stored for long periods of time and then recovered at high efficiencies and for minimal costs. In addition, these efforts have not demonstrated the short- or long-term impacts on the native water quality of the Floridan Aquifer System, a recognized potential source of drinking water.

WHAT IS AQUIFER STORAGE AND RECOVERY?

Aquifer Storage and Recovery is a relatively new concept in the management of water supplies in both potable and non-potable water systems. The concept is to inject water into an aquifer system during times of plentiful supplies, for later retrieval when supplies are limited, when emergencies occur, or to shave peak system demands at water treatment plants. The injection period occurs when plant capacity is underutilized, so that excess plant capacity can be used to create potable water supplies that can be

successfully stored underground and recovered for use in the potable distribution system without a significant amount of additional treatment.

Beneath the surface, the injected, freshwater displaces the brackish, native water occurring in the aquifer. When water demands increase to meet system demands, the excess water is no longer available, so injection is discontinued. As demand increases beyond the system capacity, freshwater is withdrawn from the aquifer (i.e., recovery). If needed, excess water can be left in storage as an emergency supply to be used during drier periods. Figure 1 illustrates the process.

Employing the Aquifer Storage and Recovery technology can improve water supply management, increase the efficiency of system operations and increase water supply availability during drought periods. By effective use of the Aquifer Storage and Recovery technology, smaller increments of water treatment facility expansions can be constructed and the water plants operated closer to average day conditions. Considerable expense can be deferred and/or saved by the more efficient operation of water treatment facilities (especially membrane facilities which are designed to run 24 hours a day).

As a result, Aquifer Storage and Recovery may be a viable method (subject to proper geologic conditions) of increasing water treatment efficiency and promoting energy conservation for many utility systems by permitting water conservation during critical times, and utilizing excess resources during plentiful periods. As applied in Florida, some or all of the excess rainfall that occurs during the wet, low-demand portion of the year (between June and October), can be injected into brackish water aquifers lying below the ground surface, and recovered during drier periods. Successful operational Aquifer Storage and Recovery systems in Florida include Peace River and Cocoa Beach.

Several utilities, including Dade and Broward Counties are currently experimenting with the Aquifer Storage and Recovery concept utilizing raw, untreated water. As most of these projects are in the test and/or permitting stage, and because they may require aquifer exemptions, their success has yet to be determined.

UNITED STATES ARMY CORPS of ENGINEERS RESTUDY EFFORT - AQUIFER STORAGE AND RECOVERY

Because of the success of the Aquifer Storage and Recovery concept in several areas of Florida, the United States Army Corps of Engineers and the South Florida Water Management District have proposed the use of the technology as a significant component of the recently completed the Central and South Florida Project Comprehensive Restudy (or Restudy), providing water supplies for environmental and agricultural users, and about 40 percent of the water dedicated to utilities. The plan specifically targets the upper Floridan Aquifer as the zone of injection, which is also the formation where some reverse osmosis supplies are derived from, thereby setting a potential future conflict with reverse osmosis supplies currently in the zone. The plan further states that "using Aquifer Storage and Recovery technology may provide greater storage efficiency when compared to the land requirements, and high seepage and evapotranspiration rates associated with above ground reservoir storage."

The United States Army Corps of Engineers notes that water quality concerns, particularly regarding untreated surface water, currently limit the ability to use Aquifer Storage and Recovery wells in the area. The quality of untreated runoff may preclude its injection for Aquifer Storage and Recovery purposes under current regulations. Retention facilities to capture and hold excess water to be injected into the aquifer may be required at some sites, increasing water quality concerns and land acquisition needs, while permitting significant evapotanspiration.

It is not surprising then that public comment has indicated that Aquifer Storage and Recovery should be tested to evaluate technical uncertainties with high capacity applications (GCSSF Technical Advisory Committee Aquifer Storage and Recovery Report, May 23, 1996). The Corps identifies several issues need to be addressed in planning for the regional Aquifer Storage and Recovery programs:

1. Environmental and health concerns regarding water quality
2. Regulatory constraints
3. Costs of the project
4. Potential benefits of having additional clean water at the chosen site.

The United States Army Corps of Engineers does acknowledge that Aquifer Storage and Recovery "should be investigated to determine its feasibility at a regional scale, as well as its environmental impacts." A significant application, provided that large-scale Aquifer Storage and Recovery is shown to be feasible, would include utilization of untreated surface water runoff and Lake Okeechobee discharges as source water to meet additional demands within the region.

Potential locations chosen for the regional, high capacity Aquifer Storage and Recovery pilot projects include sites on the fringe of Lake Okeechobee, to store excess lake water that would either be lost through discharge to tide or create harmful, prolonged high water conditions in the lake's 100,000 acre marsh. The United States Army Corps of Engineers also recommends that "sites within the Lower East Coast which could store, in the upper Floridan aquifer, water taken from the Water Preserve Areas should also be considered," and that the "possibility of conducting pilot projects at other sites, using other aquifers, should also be considered."

Regional Aquifer Storage and Recovery projects have also been proposed in association with the Water Preserve Areas, and in Dade, Broward, and Palm Beach Counties. The source of water would be surface water back-pumped into the Water Preserve Areas or canal flow. Utilization of Aquifer Storage and Recovery in these areas may increase the storage capability of the Water Preserve Areas and provide more urban water supply benefits for these areas. However, the feasibility of Aquifer Storage and Recovery projects in association with the Water Preserve Areas may be limited due to many of the same water quality concerns that face projects using untreated surface water in other areas.

A final conclusion on Aquifer Storage and Recovery from the Restudy indicates that while the United States Army Corps of Engineers "recognizes that water injected into the aquifer may not meet appropriate water quality standards, Aquifer Storage and Recovery facilities are most useful at the site of water treatment plants, where clean treated water can be injected, plant operation economies can be realized, and conveyance losses can be eliminated," which is not where the Restudy proposes to locate the facilities. It is not cost effective for large utilities to dedicate the plant capacity, the raw water, or the underground space to deriving the quantities of water contemplated in the Restudy effort (40 percent of total water).

CONCERNS ABOUT AQUIFER STORAGE AND RECOVERY ON A LARGE SCALE

Many issues remain unsolved in spite of the pronunciation of Aquifer Storage and Recovery as South Florida's water supply solution. Concerns about the proposed Aquifer Storage and Recovery systems in South Florida include the following:

1. Many of the Aquifer Storage and Recovery projects store freshwater in relatively fresh water zones for relatively short periods of time (i.e., less than sixty (60) days). The Boynton Beach project, the only active Aquifer Storage and Recovery project in Southeast Florida, by admission of the Boynton Beach staff only stores water from 30 to 45 days before they begin withdrawal. For Aquifer Storage and Recovery to work on a regional basis, or to be a long-term water supply supplement, utilities need "proof" that Aquifer Storage and Recovery can be stored for months at a time. This has been done in the Peace River project on the West Coast of Florida, and is done to an extent on Cocoa Beach; but these are the only projects where the long- term storage has been applied successfully. Both of these facilities are well outside the Restudy area so aquifer conditions will not be the same. The definition of success or efficiency of an Aquifer Storage and Recovery system has to have minimum storage time with a certain percent recovery as a sliding scale based on South Florida Water Management District and other data. Figure 2 presents a suggestion.

2. The transition zone between the fresh water and the saltwater must be defined. It has been theorized (Tom Missimer, 1969) that pumping the injectate into a zone that has a relatively thin, confined strata could clear all of the water out of the zone. Unfortunately, many of the Aquifer Storage and Recovery projects pump into "thick" zones, so the native water cannot be fully displaced. Even for large volumes of recharge, as is anticipated in the southeast coast of Florida, balance between the recharge rate and volume injected with appropriate strata needs to be defined.

   Other Aquifer Storage and Recovery projects have indicated that there is a significant mixing zone between the injected and native water, which is obvious by geometry. On the Collier County well, the mixing zone was estimated to be between 200 and 250 million gallons that

were not recoverable as a result of being in the mixing zone. The curve to define this amount shows an increase as the amount of water injected increased (see Figure 3). As a result, 100 percent recovery of the water is not achievable. Long-term storage in thick zones may create a buoyant bubble, requiring modifications to the well to prevent dispersion of the injected fluids and associated low recovery rates.

3. The injection of 1 to 1.5 million gallons per day has been proven to work for Aquifer Storage and Recovery wells in Florida. The suggestion that 5 or 10 million gallons per day could be utilized for wells has not been demonstrated, nor has the impact of injection of this quantity of water into the aquifer. If significant pressures build up in the aquifer, what is the long-term impact to the formation? And if the water pressure is reduced by withdrawal, is there the potential for collapse of the formation due to fracturing? These issues need to be addressed and resolved through large scale demonstration projects.

4. There are no rules to define, or limit, competition between water supply and Aquifer Storage and Recovery in the upper Floridan. Rules need to be promulgated to manage stored water. Otherwise, Floridan Aquifer production wells could capture stored waters. The Floridan Aquifer is known to have significant drawdowns (i.e., 1 million to 1.5 million gallons per day, per well can translate to over 100 feet of drawdown). As a result, the cone of influence spans a significant distance. Little information is available about how the Floridan system operates, nor are there any significant models that have been developed, for Southeast Florida. The concern about the water supply/Aquifer Storage and Recovery competition needs to be resolved.

5. The questions about raw water or water of less than pristine quality has long been debated by EPA. EPA's position has been a prohibition on the introduction of contaminants that do not exist naturally in the aquifer system into the aquifer. Yet with any Aquifer Storage and Recovery project, this is not possible. Logic and data collected to date does not support the impression that the Floridan is pristine aquifer. Both the surficial and the Biscayne Aquifer are known to have microbiological activity as a result of total organic carbon. The introduction of raw water with the associated microbiology, without some degree of control of the potential for growth as a result of

introduced total organic carbon of the raw water, should be questioned. Even deep injection wells that do not inject chlorinated effluent showed deterioration with time and the potential for fouling (looking at pictures or videos of the wells, one can see all of the microbiological growth on the side of the wells). However, the injection of chlorine to keep the wells clean and to provide some control of the microbiological activity close to the well creates a concern with the Florida Department of Environmental Protection related to the formation of trihalomethanes. There is an AWWA Research Foundation report that indicates the microbiological activity will reduce haleocetic acids (HAAs) almost immediately, and over a 30 to 90 day period, will remove the trihalomethanes. Likewise, the bacteria will reduce the injected total organic carbon. This does not, however, occur without an increase in the growth rate of these organisms within the aquifer, which could lead to long-term plugging or reduced well efficiency. There is a trade-off/impact that creates a new equilibrium that is yet undetermined.

6. In withdrawing this water, one concern that exists with the Floridan system is the potential for uptake of radioactivity that exists within the Floridan Aquifer in Southeast Florida. Radioactivity does not exist in the Biscayne Aquifer except in close proximity to canals that have been blasted in the limestone.

The protocol for injection on a large-scale basis has not been fully presented in a manner that can makes many utilities fully comfortable. If one assumes that utilizing a formation of a reasonable thickness, whereby all the native water could be displaced over time, the injectate would create an ever increasing bubble that would expand outward from the wells. If the concept of large bubbles, with clusters of Aquifer Storage and Recovery wells was pursued (see Figure 4), then it would not be helpful to be injecting into all of the Aquifer Storage and Recovery wells at the same time; it would, however, make sense to start at the center and work outward so that aquifer pressure would be minimized, while at the same time displacing as much of the native water as possible. Likewise, withdrawals would occur only from the center wells and not from the exterior wells. Such a protocol could be:

1. Turn on well 1 to pump/inject water

2. When bubble reaches wells 2, 3 & 4, begin injection into wells 2, 3 & 4, and discontinue pumping into well 1

3. When bubble reaches wells 5-10, begin injection into wells 5-10, and discontinue pumping into wells 2, 3 & 4. This forces the bubble to always move outward.

4. Withdraw only from the center wells

To date, this concept has not been tested.

In looking at regional-scale Aquifer Storage and Recovery projects, the South Florida Water Management District and the Florida Department of Environmental Protection should be supportive of putting together a project team to experiment with such a "ringed" Aquifer Storage and Recovery "wellfield." Should this prove successful, these ringed wellfields could be utilized around Lake Okeechobee and any one of several canal or storage reservoirs proposed with the Army Corps of Engineers' Restudy without having to use high capacity wells that might damage the aquifer formation.

CONCLUSIONS

Aquifer Storage and Recovery is a concept that will play a role in the solution to the water supply concerns in South Florida, not only for urban users, but also for agricultural and environmental users. Aquifer Storage and Recovery may be a viable method (subject to proper geologic conditions) of increasing water treatment efficiency and promoting energy conservation because Aquifer Storage and Recovery projects permit conservation of water during critical times, while utilizing excess resources in plentiful periods.

However, the reliance on large scale, regional Aquifer Storage and Recovery projects as suggested in the Restudy are of concern to many utility systems because there are no successful, large-scale demonstration Aquifer Storage and Recovery projects in South Florida. Since geology and water quality play such a significant role in the success of Aquifer Storage and Recovery projects, before moving toward the assumption that Aquifer Storage and Recovery should be as significant a component for South Florida's water supply needs, it is hoped that these ideas will provide some thoughts on the implementation of Aquifer Storage and Recovery on a contained basis in Southeast Florida. Each Aquifer Storage and Recovery well should be

designed, constructed, and tested with the unique goals of the project in mind (e.g. injection rate, storage volume, storage period, recovery rate, water quality of recharge, water quality of native, and water quality of intended recovered use). The proper peer review, and multi-jurisdictional input, in an effort to maximize the information gained, will serve to help clarify the magnitude of Aquifer Storage and Recovery's future in the South Florida regional water supply picture.

A pilot study to confirm the large scale feasibility of Aquifer Storage and Recovery is proposed by the South Florida Water Management District at Site 1. At the same time, if such a project is pursued, there should be peer review, both internally with the regulatory agencies and externally with other consultants or interested parties, so that as much information as can be gathered during this exercise, is gathered.

SOURCES:

1. Central and South Florida Project Comprehensive Restudy, U.S. Army Corps of Engineers, October, 1998.

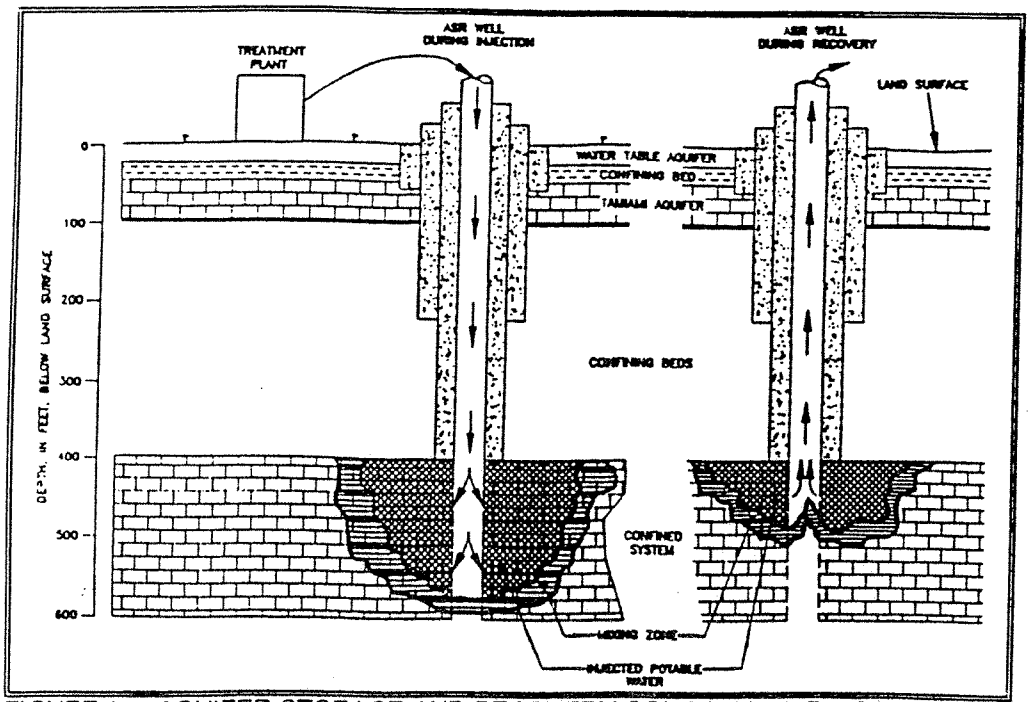
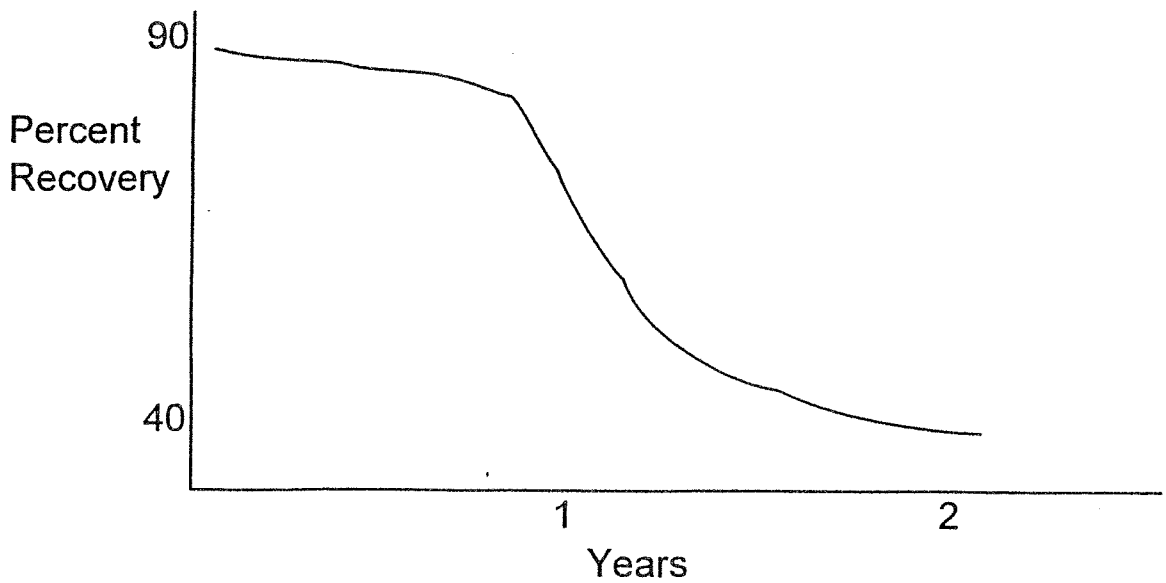


FIGURE 1 AQUIFER STORAGE AND RECOVERY CONCEPTUAL DIAGRAM FOR BRACKISH WATER AQUIFERS (AFTER MISSIMER, 1994).

FIGURE 2 - PROPOSED MEASURE OF ASR SUCCESS



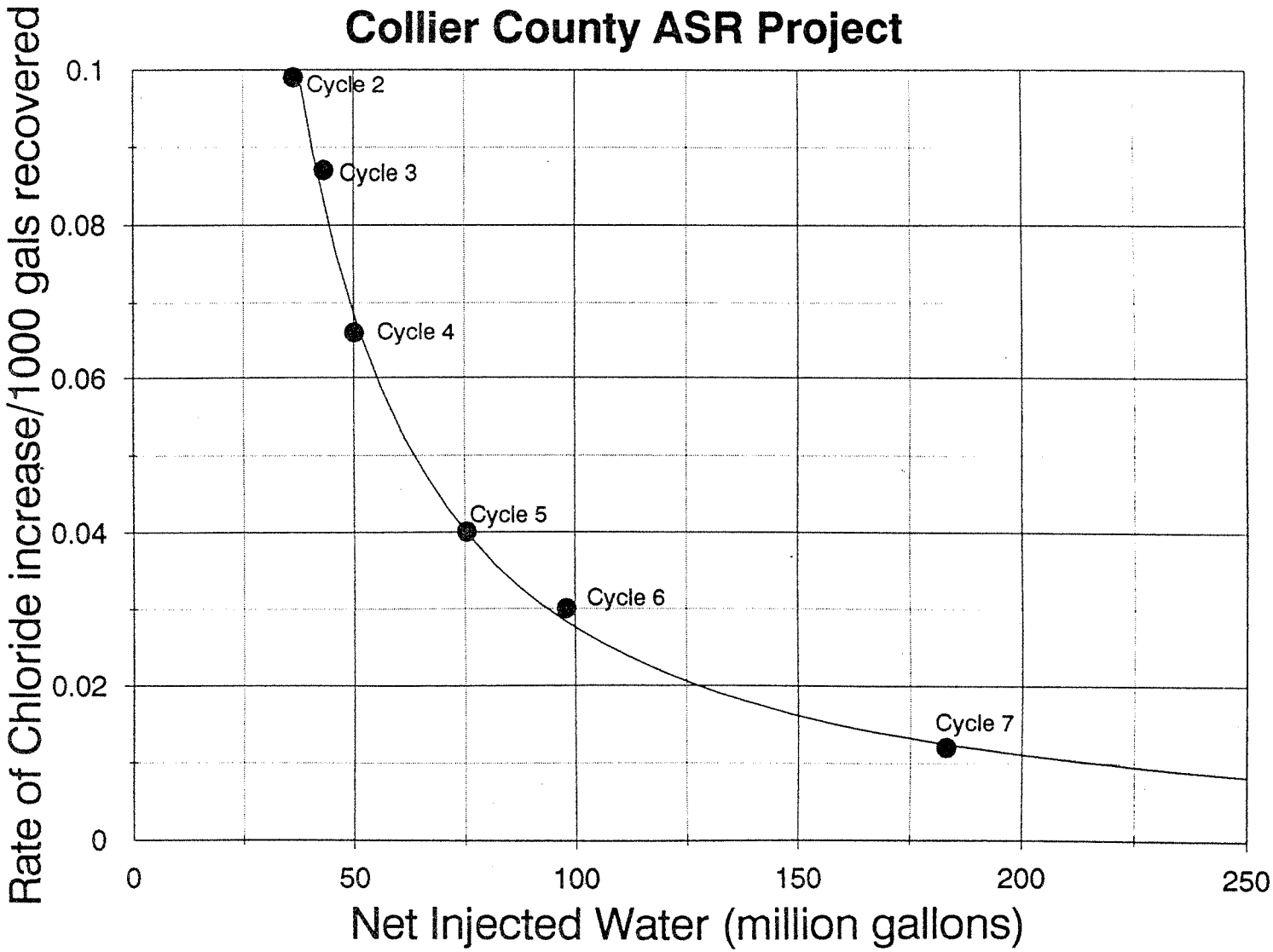


FIGURE 3 GRAPH SHOWING RECOVERY EFFICIENCY IMPROVEMENT FOR EACH SUCCEEDING CYCLE.

FIGURE 4 CLUSTERED ASR WELLS