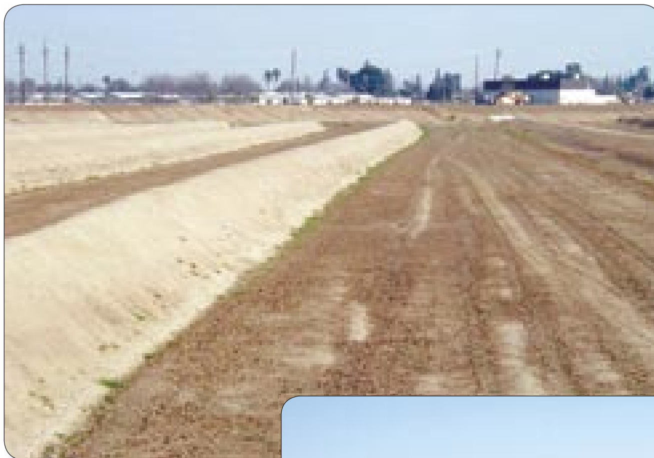
Maximizing Infiltration Efficiency at Leaky Acres

***Dennis E. Peyton, P.E.** – Sediment Solutions*

Recharge basins typically are sited in areas with relatively high near-surface permeability to facilitate movement of water into the subsurface. However, fine-grained organic and inorganic sediments tend to settle on the bottom of the basin, clogging the near-surface pore spaces. This clogging layer can reduce near-surface permeability to a lower rate than the most confining layers at depth. The basins must be regularly dried and maintained to control clogging effects. Typical approaches include: allowing the basin to dry and crack, opening up spaces between the "chips"; shallow mixing of the sediment layer with the upper several inches of basin bottom; and deep mixing by ripping as much as the upper four feet.

Leaky Acres is a 150-acre groundwater recharge facility in Fresno, California. Groundwater level is normally about 105 feet below ground surface (bgs), and the average recharge rate achieved is 0.35 feet per day, limited by the presence of two low-permeability aquitards at 30 and 60 feet bgs. The surface soils are sandy, and when freshly exposed, have significantly greater permeability than that of the aquitards.



(left) Construction of a recharge basin using the ridge and furrow design. (below) Partially filled basins showing the ridgetops exposed for wave action. Photos by Dennis E. Peyton.

To maintain the desired recharge rate, the basin was formerly taken out of service each year during a warm, dry period for approximately 45 days. During this time, the basin was drained, dried, and mechanically maintained by disking, ripping, scraping, and combinations thereof, with varying degrees of success.

The cost of mechanically maintaining a typical 10-acre basin is approximately $200 for disking, which was performed annually at Leaky Acres, and $8,000 for scraping, performed approximately every 20 years, for an average annual maintenance cost of approximately $60 per acre. Furthermore, with the basin unavailable to recharge, more than 2,500 acre-feet of recharge water were lost each year during maintenance, with an annual value of approximately $270,000, or $1,800 per acre. In light of these costs, the city of Fresno looked for an alternative method to maintain the facility that would not compromise recharge.

The Sediment Solution

For a typical basin to maintain maximum permeability, only a fraction of the surface must be free of sediment. That percentage is estimated by evaluating the permeability of the unclogged surface material compared to that of the least permeable subsurface material, the latter amount defining the basin's maximum recharge rate. A successful sediment control system ensures that an adequate

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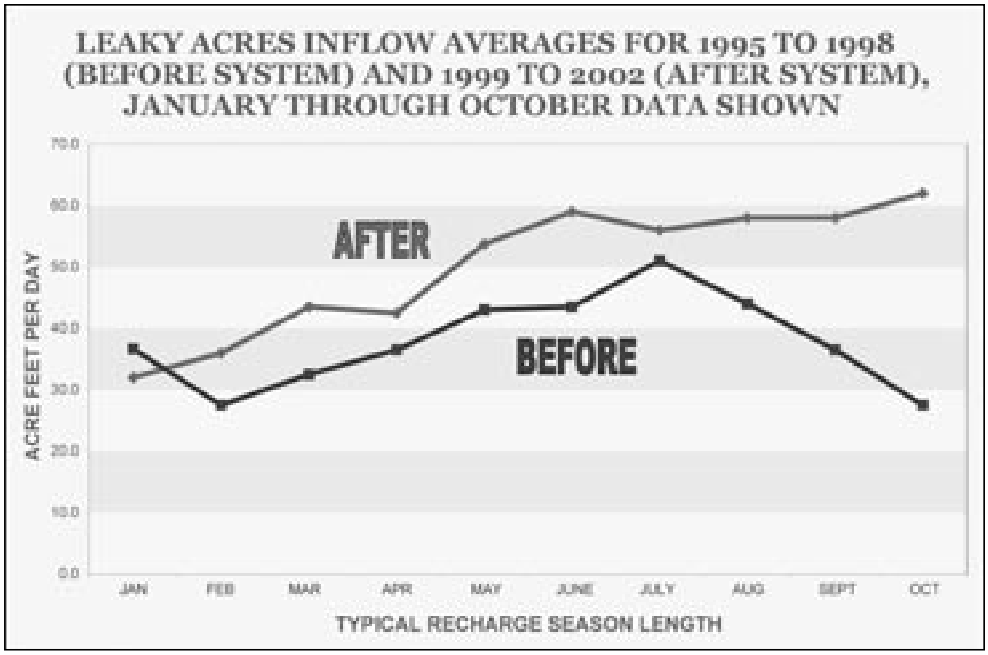

Average infiltration during the four years before the ridge and furrow design was installed, compared to average infiltration during the four years after it was operating. Note the effect of clogging in the last several months of the recharge season prior to installation, as shown by the decreasing infiltration rates. After installation, the sustained average recharge rates were not only higher, but also increasing. The system is regularly shut down for infrastructure maintenance during November and December.

percentage of surface area, as little as five to 20 percent in some cases, is sediment-free and unclogged, enabling the basin's recharge rate to be maintained at or near its maximum.

Sediment Solutions developed a basin design that keeps portions of the infiltration basin relatively free from sediment accumulation. It has been employed at Leaky Acres and more than 30 other recharge and treated wastewater disposal basins. The design is based on a recognition that sediments tend to settle and migrate to the lowest elevation available. Rather than creating a flat bottom, large, parallel ridges are constructed in the basin bottom. The ridges provide side slope areas that remain relatively sediment-free and therefore permeable. Wide, flat furrows between the ridges collect the sediment and become clogged. Continued permeability of the ridge areas more than compensates for the clogging in the furrow areas. The chart (above right) shows recharge rates at Leaky Acres before and after installation of the ridge and furrow design. The additional water recharged now averages 4,175 acre-feet per year. At the current market value of $100 per acre-foot, the new design is generating an additional $417,500 per year for Leaky Acres. In addition, maintenance costs have been significantly reduced, saving approximately $12,000 per year.

Maintenance with Less or No Equipment

In most applications, the submerged ridges sustain their permeability with only periodic dewatering for maintenance. Operating the water level just above the top of the ridges takes advantage of surface wave energy to minimize the accumulation of fines on the upper areas of the ridges. Over time, however, inorganic and organic loading may impact the permeability of the submerged ridges; how quickly this occurs depends on the quality of the source water and other environmental conditions.

When ridge maintenance is required, one method is to lower the water level in the basin. As the water level reaches the top of the submerged ridges and descends along the side slope, wind-induced waves re-suspend many or all of the accumulated sediments, which migrate toward and ultimately into the furrow area, as the water level continues to descend toward the furrow. This method does not require emptying the basin, drying it, or use of heavy equipment that can compact the underlying sediments: a significant improvement over previous methods. Drying just the ridge surfaces (with water standing in the clogged furrows) has also proven useful for desiccating algae deposits on the ridge surfaces and restoring ridge permeability.

Sediment Solutions is currently developing a ridge-cleaning tool to relocate the sediment and surface fines that collect on ridges where dewatering by wave washing is impractical. The tool will loosen the surface clogging layers and direct them toward the furrow area using shear, water, and gravity forces. The prototype model has been used with an outboard motorboat while the ridges are submerged. Both the ridge and furrow design with wave washing system and the ridge cleaning tool process are U.S. patent pending.

For additional information, contact Dennis Peyton at depeyton@hotmail.com or 559-360-3079.

Wave washing by boat to clean ridges. Photo by Dennis E. Peyton.

Riparian Restoration on Nutrioso Creek, Arizona

***Jim Crosswhite** – EC Bar Ranch*

(above) Nutrioso Creek at EC Bar Ranch; (below left) planting willow seedlings; (below) installation of stream stabilization structures. Photos by Jim Crosswhite.

In 1996, I acquired the EC Bar Ranch, a 300-acre spread located in the White Mountains of northeastern Arizona. The ranch included a 1½ mile stretch of Nutrioso Creek; another mile of this riparian area was added in 2000 through the purchase of an additional 100 acres.

The land presented numerous challenges from the start. Upland pastures were infested with rabbitbrush and sumac. Blue gramma, the predominant grass species, yielded only 300 pounds per acre. Due to lack of vegetation and eroding streambanks, the riparian area was essentially nonfunctional. The earth ditch irrigation system was in disrepair and fencing was altogether lacking.

Water quality in Nutrioso Creek also presented a significant problem. A report released in 2000 by the Arizona Department of Environmental Quality (ADEQ) identified excessive levels of turbidity along seven miles of the creek. With four fish species inhabiting the creek, including the endangered Lower Colorado River spinedace minnow, turbidity had the potential to adversely affect both irrigation water and property rights. But ADEQ's report on total maximum daily load (TMDL) for turbidity also offered numerous recommendations to improve water quality that have been successfully adopted:

1. *Confine livestock grazing in the riparian areas* to the dormant winter months. Twenty riparian and upland pastures have been set apart to allow rotational grazing of livestock, and the riparian area is now fenced to exclude elk. The USDA Environmental Quality Improvement Program (EQIP) provided matching funds for brush management to improve upland pastures, and cross fencing to allow rotational grazing.

2. *Install stream grade stabilization structures* to protect streambanks during high flow events and reduce water velocity. Also with help from EQIP, more than 15 such structures were installed to raise the streambed and create a floodplain in deeply gullied channel reaches.

3. *Provide alternative drinking water sources* for wildlife and livestock. The Arizona Water Protection Fund helped to pay for the drilling of several off-channel water wells and installation of 15 wildlife drinkers so that cattle, elk, and other animals would not have to access the stream directly. These projects protect revegetation projects along the stream corridor and allow more water to remain in the stream itself.

4. *Revegetate the riparian corridor* with grass and willows. The seedings and plantings were aided by sprinkler irrigation until they were established. Inefficient earth ditches, which lost 100 million gallons of water each year due to seepage and evaporation, were replaced with sprinkler irrigation systems supplemented with pipe,

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water storage tanks, water pumps, and aluminum irrigation pipe, to cover 200 acres of upland and riparian pastures.

5. *Eradicate rabbitbrush and replace it with grass*, providing more grass per acre and reducing livestock reliance on vegetation within the stream corridor. Upland pastures were mowed, root plowed, and reseeded. Buffer strip areas were created. Erosion has been reduced, and forage production increased tenfold.

Prior to restoration efforts, the creek periodically dried up under mild drought conditions, causing loss of habitat for all fish and many other wildlife species. In three of the last four years, which were characterized by severe drought, Nutrioso Creek has been dry upstream and downstream from the property, but pools and running water on EC Bar Ranch have kept alive the vegetation, fish, and other wildlife that are dependent on the riparian area. In 2002, the condition of the riparian area was rated by an independent consultant as “on an upward trend,” with many places “in proper functioning condition.”

More partnerships are being developed to extend water quality improvement practices downstream, increase wildlife habitat, and improve ranching economics. Those interested in applying best management practices on their property may also find riparian fencing, dormant season livestock grazing, and willow plantings to be basic yet very productive and cost-effective practices to implement.

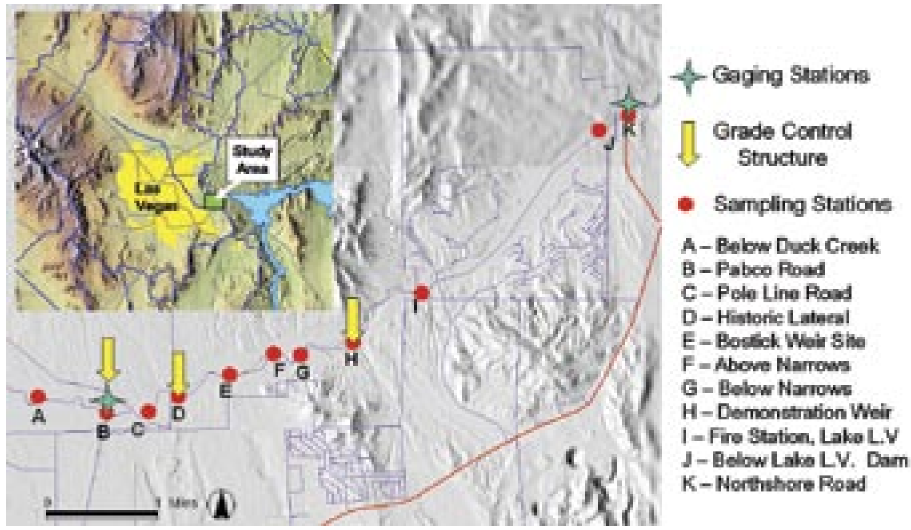
Visit ECBarRanch.com for more information.

Dye Tracers Help Quantify Flow at Las Vegas Wash

***J. F. Leising** – Southern Nevada Water Authority*

The Las Vegas Wash drains the 1,600 square-mile Las Vegas Basin and terminates in Lake Mead on the Colorado River (see map). An ephemeral stream prior to its use as a wastewater outlet, its discharges to the lake currently average around 260 cubic feet per second (cfs), of which surface flows and gains from groundwater each contribute approximately 17 cfs. The remainder derives from highly treated wastewater and exhibits strong diurnal variation between about 140 and 280 cfs and significant irregularity at time scales on the order of minutes. Two automated gauging stations are maintained by the U.S. Geological Survey (USGS) to record flows in the lower wash.

Southern Nevada Water Authority (SNWA), the region's principal water purveyor, is actively pursuing engineering activities and scientific investigations relating to Las Vegas Wash because it discharges into Lake Mead, from which 90 percent of Las Vegas Valley's water supply is obtained. These investigations have included development of a conceptual hydrogeologic model of the wash in conjunction with ongoing water quality monitoring for various contaminants of concern in the wash and in Lake Mead.

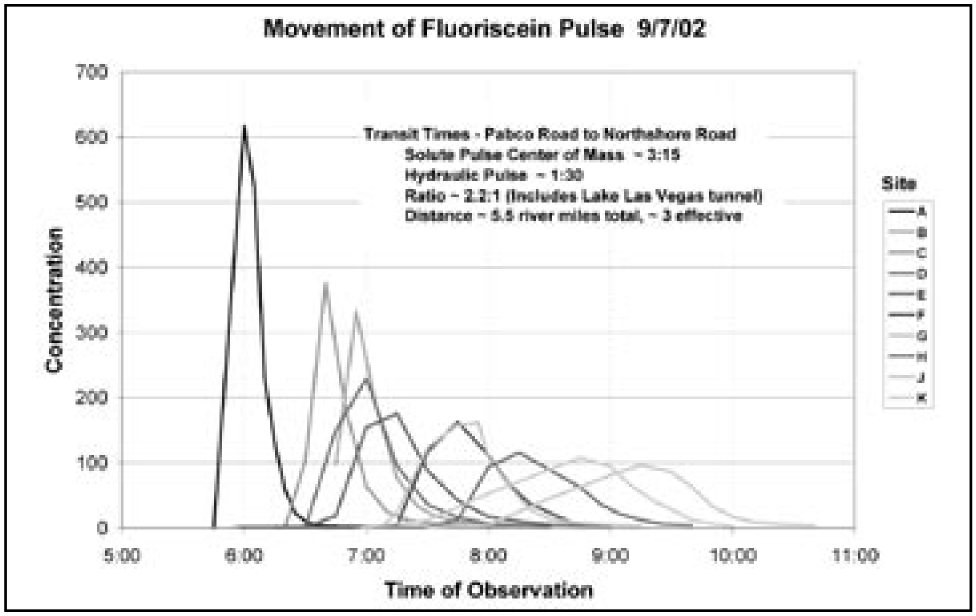


Location of dye tracer investigation along Las Vegas Wash.

Conceptual Hydrogeologic Model

Las Vegas Wash flows over saturated, unconsolidated gravel, sand, and silt. These deposits rest upon and interfinger with more indurated and less transmissive alluvial deposits. Beneath them lies older clastic bedrock that is frequently gypsiferous, clay-rich, and relatively impermeable, but locally contains discontinuous silt, sand, and fine gravel lenses of higher permeability.

Shallow, contaminant-bearing groundwater migrates laterally, and either enters the unconsolidated sediment, emerges as surface seeps prior to entering the wash, or moves further downstream in the unconsolidated deposits. Bedrock obstructions deflect this water upward, augmenting surface flow and introducing additional contaminants.



Peak fluorescein concentration in the Las Vegas Wash.

Dye Used to Measure Flow

To try to quantify the shallow groundwater contribution to Las Vegas Wash, SNWA conducted a dye tracer investigation in September 2002. In a steadily flowing stream, discharge is measured by injecting dye at a known concentration and constant volumetric rate for a time sufficiently long to fully disperse the dye, so that a steady-state concentration of dye can be assumed for the duration of the test. Samples are then collected at a series of downstream points. Assuming a mass balance, gains and losses to the stream can be calculated from the dye concentration, provided there are no losses from the system.

Field Methodology

The dye tracer test was conducted along a 5.5-mile reach of the lower course of the wash. However, because the highly variable flows of the wash could cause the dye concentration to fluctuate through time, the standard dye-tracing methodology described above was modified as suggested by Dr. Kenneth Heim, of ENSR in Wexford, Mssachusetts. Rather than injecting a single dye, SNWA released both rhodamine-WT and fluoriscein dyes, each readily detectable by fluorometric methods at very low concentrations. First, rhodamine was introduced to the upstream end of the study area at a constant rate for about 28 hours prior to sampling. This allowed time for the dye to disperse along the course of the wash. The following morning, a single pulse of fluoriscein was released.

At each of ten stations, volunteers collected multiple discrete samples at times chosen to bracket the arrival of peak fluoriscein concentration. Samples were preserved and analyzed in a laboratory. Sample standards were prepared ahead of time to account for dye sorption, photolysis, temperature, and spectral interference.

Results Allowed Quantification of Surface and Shallow Groundwater Flow

Although the pulse dispersed longitudinally as it translated downstream, its peak was easily recognized during the laboratory analysis (see chart above). Total flow was computed from the rhodamine concentration in the samples bracketing the fluoriscein peak. The results compared well with stream discharge measurements at station C that were made during the field activities and with corrected gauge readings. Between sites A and D, gains from groundwater were approximately 3, 4, and 0 cfs, respectively. Between stations J and K, the gain was 3 to 4 cfs. Elsewhere, seepage flow beneath drop-rock grade control structures complicated the interpretation of downstream dye results.

The dye tracer study led to a better understanding of hydrologic processes operating in the wash, including quantification of gains along certain reaches and the development of flow systems behind grade control structures. These results have aided contaminant mass balance determinations, provided input to the Nevada Department of Environmental Protection's groundwater flow model, and contributed to estimates of salinity gains from shallow groundwater. Further investigations are being evaluated.

The author expresses his appreciation for the voluntary labor contributions of personnel from SNWA, the USGS, and the Lake Las Vegas Resort in collecting the field data. For further information, contact Joe Leising at joseph.leising@snwa.com.