Agricultural Irrigation Using Municipal Effluent

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Abstract. *The paper describes the development of a design and management plan for disposing of secondary effluent originating in the urban communities. It highlights the differences in approach that a public utility must take, versus a typical agricultural irrigation application. Costs and requirements for municipal effluent irrigation are many times greater. The complexity of regulations and agency procurement procedures relegates the actual irrigation system design to a relatively small role in the total project.*

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Introduction

An irrigation project involving the application of secondary effluent is very different from a typical agricultural irrigation project. Costs and complexity are many times greater because of (i) the way municipal utilities are accustomed to doing business, and (ii) the involvement of numerous regulatory agencies that range from local county governments to the US Corps of Engineers to the State Regional Water quality control board. These agencies and utilities take the project out of the hands of the farmers and designers and add multiple unique layers of issues into the system design and implementation.

Typical Agricultural Irrigation Approach

In a typical agricultural center pivot application on a farm that is not utilizing secondary effluent, a farmer will call up one or more irrigation dealers and get a quote for an irrigation system. The dealer will give the farmer a price with very few detailed specifications. The decision about which dealer to select may be based more on personal comfort levels than on price and detailed bid specifications. No permits are typically needed for the installation. The dealer installs the pivot and the supply pipe (if needed) and cable. Either the dealer or a local pump company will install the well, pump, and pump driver (electric or diesel, for example). Everything can be done within a very short time period.

The farmer already knows how to farm, and has the required equipment for land preparation, seeding, harvesting, etc. If the farmer is lucky, there will have been conversations about possible runoff problems and wheel ruts and how to deal with them. If the farmer did not have a good irrigation dealer, the farmer will somehow, over a few seasons, learn how to deal with those problems. A little bit of runoff and spray loss is usually no big concern.

Public Utility Approach to Irrigation

For a utility that decides to dispose of secondary effluent via agricultural irrigation, there is a completely different approach. The utility will generally pursue the following course of action (abbreviated here):

1. Feasibility studies of the property must be conducted by various consulting firms. They will examine the water supply and water quality, develop soils maps, compile GIS maps that include boundaries and topography, study the extent of high water tables in the area, etc. This will take a few years.
2. The utility will then need to obtain a whole range of initial permits, from county government to regional water quality control boards. Each agency will add special requirements to the package – including those related to appearance, mitigation of wetlands, etc.
3. Another consulting firm will examine the feasibility of irrigation, and make recommendations regarding how many acres can be farmed, where they will be, and what methods of irrigation should be used. Up to and through this step, commercial agronomists and irrigation dealers have not been involved.
4. Using the preliminary irrigation design, the utility will issue a Request for Proposals (RFP), receiving responses from a variety of consulting engineering firms. The RFP will describe the needs for engineering services to include the final design of the irrigation system and drawings and specifications. The selected engineering firm will also be responsible for responding to requests from various regulatory agencies, obtaining various permits, performing more detailed topographic and soil surveying, etc.
5. The selected consulting engineering firm must then examine the available information and recommendations, and decide if/what changes should be made. Detailed design and specification documents must be developed, and cost estimates must be made. A complete farming plan is also generally needed, with advice regarding the crops to be planted.
6. The design then goes through numerous iterations as comments are received from other agencies, continuously morphing until a final project is identified. At this point, the project goes out to bid.
7. Because public utilities are accustomed to working with general contractors that handle a complete project via one contract, the utility will usually favor having one contractor be responsible for the center pivots, the piping, pumps, remote monitoring, soil moisture sensors, construction of reservoirs and concrete structures, berms, and land preparation – all done in accordance with detailed specifications and drawings that are typical of civil engineering projects such as bridge construction or building design.

The Contrast

For a typical farmer, almost everything is related to just getting a pivot installed and operating. The farmer does not expect to see detailed drawings of everything, and the irrigation dealers will field-fabricate parts and pieces as necessary. Irrigation dealers will have minimal drawings, and instead rely on an installation crew that is very familiar with that type of installation, and which can improvise when needed. If a concrete block somehow appears in a field, the dealer will make adjustments on the spot and remove it or go around it. The utility approach is quite different; it is expected that everything be defined in advance. On-the-spot adjustments are not expected.

A farmer will also contract independently with various companies for unique services. For example, the farmer would usually not expect the irrigation dealer to also know about fertilizer mixes and the details of irrigation scheduling. The farmer will obtain farming equipment from one source, fertilizer from another, the pumps and electrical from a third source, and the pivots and piping from a fourth source. In this way, the farmer hopes to "cherry pick" or select from the best available expertise or equipment for each function. In a sense, the farmer acts as the general contractor and arranges for each of the "subcontractors".

A public utility, on the other hand, has established procurement procedures. As a public agency, it must open the bidding process to a wide range of companies. So the specifications must be very tight so that everyone is bidding on the same package. Furthermore, since it is not a "design/build" project, it is expected that all of the details are presented in the bid package so that there are very few, if any, unknowns for the contractors.

Another big difference is that utilities generally have a policy of not wanting to favor one brand or model over another. This has merit, of course, but it is also problematic in the agricultural irrigation world. The fact is that there can be substantial differences in quality and performance between various brands and models. A reputable irrigation dealer will know, through experience, which brands and models will function well and continue to function over time. The dealer will know that although the written specifications of product "A" and product "B" may look the same, it could be devastating to use product "B" because of poor quality control.

This type of judgment cannot enter into the bid package of the utility. Instead, the utility will require that the consulting engineer write very detailed specifications (hundreds of pages long) to avoid getting inferior products. But since the consultants often have very little field experience with agricultural irrigation systems, this is problematic.

The bid package documents must also follow utility specifications that require complex insurance coverage, adherence to various pay rates, and numerous other contract-related items.

In the end, the project documents are so exhaustive that a typical irrigation dealer is likely unable to bid on a project for one or two center pivots. The process will be dominated by activities and concerns that usually fall outside the normal scope of work by irrigation dealers. Therefore, the dealer will be one of several subcontractors on the job and primarily function as a supplier of equipment and installation, as opposed to a supplier of technical expertise.

Environmental Considerations in Design and Management

There are good reasons for the involvement of regulatory agencies in the review of secondary effluent irrigation applications – although sometimes the involvement can be excessive and unrealistic. Secondary effluent can have two problematic constituents not found in typical agricultural irrigation projects: (i) disease-causing organisms, and (ii) high nitrogen loads. Because of these concerns, a number of careful precautions must be put into place.

Runoff and Wind Drift. The extent of disease-causing organisms will depend upon the extent of the effluent treatment. In some cases, large devices and clumps of various materials will appear in high quantities in the irrigation water. In such cases, not only are there health issues, but filtration becomes very important. In other cases, the secondary effluent has been filtered and chlorinated before reaching the irrigation system. It is not drinkable, but it won't plug sprinklers. In all cases, however, people do not want to see even a drop of effluent irrigation water spraying or drifting across the fence or running off a field. Drivers on county roads who get a wet windshield tend to become agitated. Bikers become even more agitated when they get wet with effluent water.

Special consideration must be given to the sprinkler packages to avoid wind drift of spray/sprinkler droplets. This means that end guns may not be a viable option, for example. Instead, sprinklers that rotate at relatively low pressures and that can be suspended relatively low are ideal. Center pivots are often the irrigation method of choice for large installations because of their relative simplicity, low cost, and the ability to remotely control them and minimize human contact.

Due to the controllability of pivots, they can easily be managed to not operate during windy times of the day, by turning on and off either manually or automatically. This, of course, requires a reservoir buffer for the water supply – which is generally a part of any effluent project because the flow rate from a treatment plant will not be constant.

Surface runoff can also be a major consideration, especially during a rain. Regulatory agencies generally require that no surface runoff be allowed. This means that berms must be constructed with some type of pumpback and storage system. The sprinkler package must also be selected to minimize runoff, and the pivot rotation speeds are generally set as high as possible in order to maximize evaporation (completely different from typical production agriculture) and to minimize runoff.

Because some effluent water has a high percentage of sodium, it is important to assess the water and soil quality and attempt to preempt water-quality related infiltration problems. While water-applied gypsum treatments can be valuable, their complexity often leads to high soil-applied gypsum treatments to counter the influence of sodium. Special attention also needs to be paid to surface roughness. For example, if furrows are used they should be on the contour if possible, and dammer-dikers can be used to temporarily store small amounts of runoff.

Nitrogen. The dominate factors regarding nitrogen in secondary effluent that impose special requirements on irrigation system design are:

1. The nitrogen concentrations are much higher than in irrigation water.
2. Some deep percolation of irrigation water will always occur due to non-uniformity and timing issues. Rainfall cannot be completely anticipated and will often cause additional deep percolation.
3. Regulatory agencies will limit how much nitrogen can deep percolate, in an attempt to protect the quality of the groundwater and surface water supplies.
4. Regulatory agencies will generally require some type of field verification program that demonstrates adherence to regulations about not contaminating the groundwater with high nitrogen loads.
5. The flow rate from sewage treatment plants is relatively constant throughout the year, but the evapotranspiration rate of irrigated plants is quite variable; it is highest during the summer and lowest during the winter.

Cropping Patterns. A cropping pattern must be developed that will consume the irrigation water plus the nitrogen. Alfalfa is a legume that is capable of fixing atmospheric nitrogen to meet its nitrogen needs, but if other nitrogen sources are available (for example, from the irrigation water), alfalfa has a preference for these other sources. Alfalfa is also a crop that has a relatively high annual evapotranspiration (ET) rate.

However, having only alfalfa as the irrigated crop can only be successful if there are huge storage (reservoir) facilities that can store winter treatment plant flows and apply that effluent to the fields during the summer. The reservoir is needed because the variable ET of alfalfa is not compatible with the constant sewage treatment plant outflow. This is the strategy that the Los Angeles County Sanitation Districts (LACSDs) now uses in the Palmdale and Lancaster projects for which ITRC provides irrigation management and monitoring services. The South Tahoe Public Utility District design, which ITRC is currently working on, has a similar reservoir storage capacity.

Another cropping strategy is to vary the acreages of different crops to create a relatively constant ET rate throughout the year. This was an early strategy by LACSDs in Palmdale and Lancaster, and the ITRC-developed cropping pattern and water management was definitely more complex than with a large seasonal reservoir. Varying the crops also requires a very large acreage, because the ET rate is low during the winter. ITRC used a combination of perennial alfalfa plus winter small grains to meet the objectives of consuming both nitrogen and water.

Irrigation System Distribution Uniformity. Irrigation systems for effluent disposal require higher-than-typical distribution uniformities (DU). An excellent DU helps to minimize deep percolation, but just as important is the need to be able to have excellent soil monitoring. Regulatory agencies will typically require extensive monitoring of soil moisture contents as part of the verification program. The concept is very simple, but in reality, if different parts of the field have different applications of water, the soil monitoring can become fairly meaningless. It is difficult enough to get good soil moisture readings in uniform soil moisture conditions; having different application rates can make the monitoring program incredibly complicated.

Crop Uniformity. Residual soil moisture (which results in deep percolation) is impacted by uneven crop ET rates across a field, just as it is impacted by uneven water application rates. Therefore, it is important that highly monitored fields have uniform crop growth. This requires special attention to spatial variability of nutrition and soil types, and the development of spatially variable treatment programs.

Irrigation Scheduling. Assuming that water is applied uniformly, and crop ET is uniform across a field, the next concern regarding deep percolation management is the correct estimate of crop ET rates. This requires a mix of classical weather-based procedures and soil moisture monitoring. However, for effluent disposal the scheduling is somewhat more complex because a serious attempt must be made to anticipate rainfall events in order to deliberately dry out root zones so that as much rainfall as possible can be stored within the root zone (as opposed to deep percolating).

An additional layer within the irrigation scheduling is the nitrogen balance. For regulatory purposes, both the water and nitrogen must be consumed. Plant nitrogen uptake rates must be estimated and then verified with frequent plant tissue samples.

Verification and Reporting. As mentioned above, regulatory agencies may require that the public utilities submit quarterly and annual reports that provide evidence of good management and verification. This is a major economic consideration. It requires an excellent monitoring program that involves soil moisture and nitrogen sensors, flow rate measurement to individual parcels, crop pattern reporting, verification of irrigation system DU, automated weather station data and ETo values, etc. All of this information must be organized for both daily scheduling/management purposes and for the reports.

Summary

A casual glance at an agricultural irrigation system used for effluent disposal will give no indication of the costs, or of the efforts required for design, planning, management, verification, and reporting. What to an irrigation dealer should be a simple, inexpensive center pivot design is in fact a part of a very complex process, most parts of which fall outside the realm of agricultural irrigation dealers. In current secondary effluent irrigation projects, the design/bid process is generally structured so that the dealer is only a provider and installer of equipment as specified by others. However, the design of a successful system requires the special expertise that, in many cases, the dealer has but the utility's contractor does not. A major challenge is to bring the dealer's expertise into the process at the earliest possible time and in a manner such that the knowledge and expertise of the dealer can be effectively used.