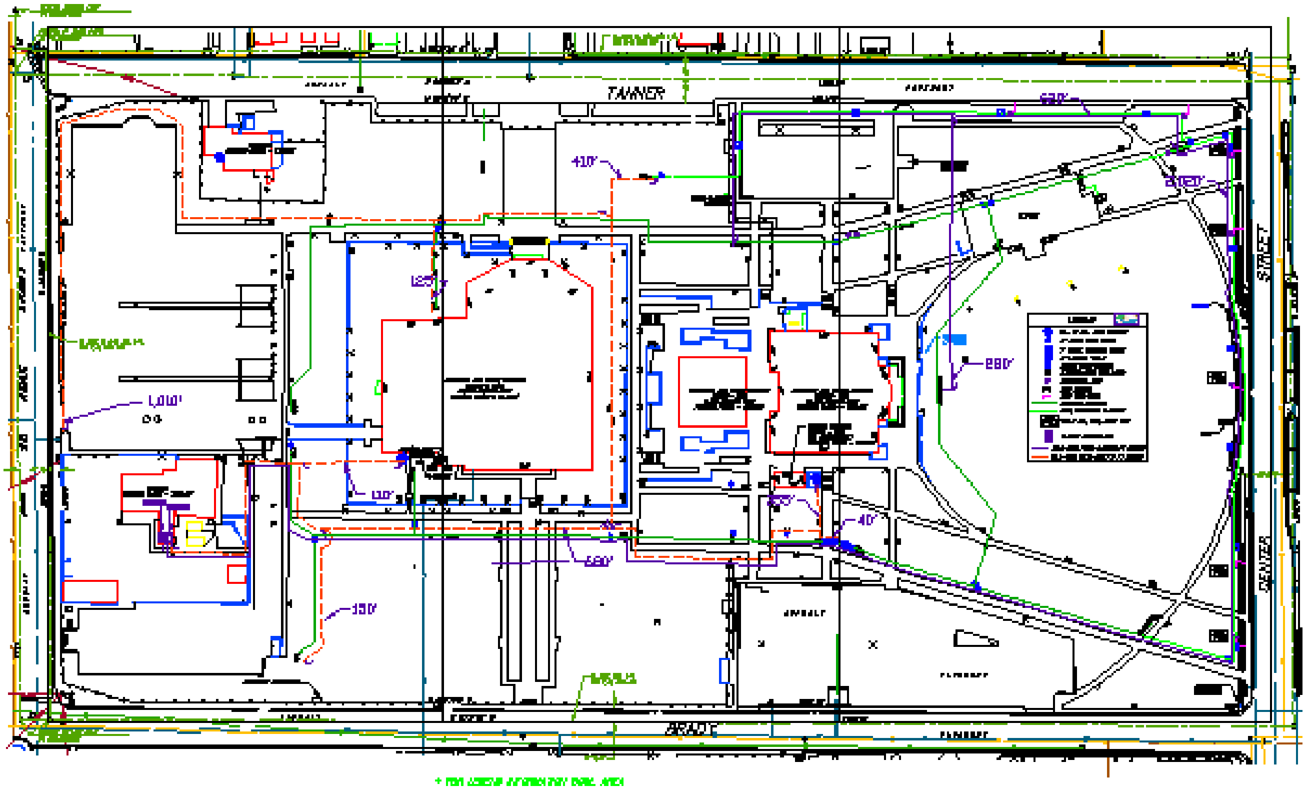
Case Study 2
Arizona Swing Syndrome Academy– Irrigation Infrastructure Renovations - 2009

Arizona Swing Syndrome Academy (ASSA) is a vast special-education institution, centered on the equestrian sciences, in Mesa, Arizona for adults suffering from Swing Syndrome. The facility offers accredited Bachelor of Science degrees in equestrian science and horsemanship, as well as preparation for veterinary-technician certification. The campus supports about 9 acres of Common Bermuda grass, and about 2 acres of lush flower beds, shrubs and numerous species of trees, some of which are quite unusual. Interspersed throughout most of the turf are turf-friendly trees, including Olive, Citrus, Palm, and Cypress.

Irrigation systems are conventionally wired, meaning that a solid-state controller is wired to each remote control valve by a common wire, and a valve control wire. This means that in the trench leading away from each of the (8) controllers, out to the field valves, there can be 20 to 30 control wires, along with the one, or just a few, common wires.

Randy Young has been the Superintendent of the landscape and irrigation crews at ASSA since 2000. During this time, Randy has improved the irrigation system in many ways, particularly in updating sprinkler heads, adding some sub-surface drip irrigation where appropriate, replacing difficult to operate controllers, and installing new control wires. For such a large, important institution to still be configured like systems going back to the '60's, is repugnant to Randy. "I depend on volunteers to help maintain this non-profit facility. I just don't have the time to make adjustments to my irrigation schedules by visiting to each controller." Randy has a degree in horticulture, and 13 years of experience, so his boss generally listens when Randy reports on his work, his issues and his objectives. He has also been approached by various irrigation equipment distributors about upgrading the system to a 2-wire, centrally controlled system, bringing the system into the 21st Century.

Randy also wishes to replace all of the remote control valves, the mainline isolation valves, and add capacity with another water meter if it is needed to allow all irrigation to be completed within a 9-hour water window.



Scope of Work

Late in 2008, Water Balance became aware of a consulting opportunity at ASSA. Randy had met Tom Reynolds, one of the principles of Water Balance through another acquaintance. So Tom and Randy started discussing the project, and how it would likely go in phases. Phases that allowed making the upgrades as small secondary additions to other larger, capital improvement projects which ASSA Directors had already budgeted in their 5-year forecasts.

Tom's challenge was complementing Randy's existing vision, and recognizing that two heads are generally better than one, but no two heads are bound to be found walking in each other's shoes. Randy would have to be the driving force, while Tom could succeed if he learned how to listen, and how to contribute effectively. In other circumstances, consultant's respond to a Client's Project Manager, who assembles the design team to prepare construction documents. The scope of work is defined by the PM, and specifies what consultant's must be capable of, and convince the Client of this in a presentation. In the case described here, Water Balance developed a scope of work, and offered it to the Client to modify.

Excerpt from Actual Proposal

Proposal for Irrigation System Modifications

Background

Construction of the Arizona Swing Syndrome Academy (hereafter "Client") was completed in 1967, then the only such facility in the US. One earlier irrigation system has existed, and remnants still remain, though hidden, buried under lush foliage and lawns; the current (second) system is generally good condition because it has been maintained. Additionally, a flood irrigation system has been maintained and is used periodically for various needs, principal among them to deep water hundreds of specimen and heritage trees.

Approach

As a standard practice, a pre-project planning process, ranging from very informal to very formal, depending on project scale, clarifies what projects are intended to accomplish, in a reasonable degree of clarity and as efficiently as possible. This practice insures that the Scope of Work is sufficiently clear and accurate, not subject to substantial clarification later.

A Pre-Project Planning process would (should) consider:
project objectives (e.g. business, economic, aesthetic, other);
project constraints (e.g. budget, schedule, regulatory, other);
the basis for the design (e.g. site data/requirements, utilities data/requirements, facility programming/requirements, equipment/technology requirements, alternatives to be considered);
project execution approach (e.g. staging, procurement strategy, delivery method, other);
project monitoring and control procedures (e.g. quality, cost, schedule, other).

GENERAL SCOPE OF WORK– Also See Appendix A - Special Provisions
Intent of Design: This Scope of Work provides determining the requirements for irrigation systems and irrigation control systems, as well developing their design and construction specifications, all in accordance with industry-accepted operation and maintenance practices and standards. It also delineates the responsibilities of the Designer in developing the design and overseeing its construction.
Design Mission: Our goal is to achieve sustainable, well-maintained facilities with attractive and healthy landscapes. Important objectives include water conservation, reduced maintenance needs, reduced chemical use, erosion control, and the health, safety and welfare of the general public.
Qualifications: Individuals participating in the design of irrigation systems shall either have or be under the direct supervision of an individual who has the following qualifications and credentials:
Professionally-Licensed Agricultural Engineer or Certified Irrigation Designer (CID) with minimum 5 years of experience in design of commercial irrigation systems;
DESIGN PRODUCT
The design product shall include the following elements, as applicable in the Design contract:
Irrigation Concept Plan: A complete description of irrigation measures proposed by the designer based on the landscaping plan and the criteria provided herein, consistent with industry-accepted practices, and in accordance with the scope of work established by the Designer's contract or agreement with Client.
Utility Impact Report: The Irrigation Concept Plan shall be accompanied by a Utility Impact Report that quantifies expectations in terms of annual water usage, and operations/maintenance costs for the proposed irrigation concept(s). This report shall be prepared using the format and applicable labor and utility rates provided by Client at the request of the Designer, such request being made at the time the report is prepared.

Drawing Set: A complete set of drawings showing all site preparation, demolition, installation, system components, and instructions necessary for successful construction of the approved Irrigation Plan.
Final Technical Specifications: The Designer shall prepare Final Technical Specifications, unless waived by Client.
Controller Commissioning: The Designer shall be responsible for working directly with the Client representative as needed to coordinate all commissioning activities and ensure that they are successfully carried out prior to substantial completion of the irrigation system construction. The commissioning activities shall confirm that the system is operating at the optimum level anticipated by the design, and that the controlling software has been correctly and completely programmed.
As-Built Drawings: The Designer shall submit a complete as-built drawing set within 10 calendar days of substantial completion, developed in accordance with the process outlined below. The Designer shall verify that the Construction Contract Project Manual is completed in a manner that contractually obligates the Contractor to follow this process.
The Contractor shall keep a current working set of drawings with all as-built changes or actual conditions as work proceeds, to be submitted to Designer at substantial completion of irrigation system installation.
The Contractor shall arrange for surveying services to locate all piping and equipment with trenches open as system is constructed, with survey data properly recorded into field books.
The Contractor shall perform all required tests, audits, etc. with adequate notice as detailed in the specifications.
The Designer shall interpret and incorporate field information into a scaled AutoCAD drawing (utilizing same scale as contract documents) and provide to the Park Engineer prior to final acceptance of project.
The Designer shall prepare Mylar record drawings ("as-builts") with contractor's and Client surveyor's information included, and CD(s) containing electronic AutoCAD drawings with that same information, to be submitted to the Owner along with all other required information, manuals, etc.
ESTABLISHMENT OF IRRIGATION CONCEPT PLAN
In general, irrigation system layout and capacity shall be consistent with the nature and extent of plantings established as part of the landscaping plan provided in accordance with the design contract. Irrigation designs shall consider site specific criteria including: soil type, slope, plant root depth, similarity in plant water needs, microclimates, weather conditions and water source.
Discovery Phase: Project requirements of existing landscapes programmed for renovation shall have a Discovery Phase that includes:
Static pressure record over 72-hour period, including one Saturday.
………….

Job One – Select the Brand, Distributor, and Support of the 2-Wire System

Several manufacturers would like to see their product placed at ASSA. The facility is smack-dab in the center of Mesa, and draws 10's of 1,000's of visitors each year, who just like to enjoy the shady gardens. Irrigation culture is about as deep and rich as it gets anywhere in Mesa, short of the Euphates.

Randy and Tom narrowed the field of prospects themselves, given their collective 40+ years of background in the subject, though they asked one Landscape Architect that was familiar with the institution. Like any purchase decision, buyers must weight all of the features and historical records of the manufacturer's and their products to gauge where the real value lay. One product may offer hydraulic-based flow management, while another does not. None of the systems may offer dynamic flow monitoring, flow accumulation, which constitutes the first rule of water management: Measure the water you apply. Two systems requires on-site weather stations, the other requires significant numbers of soil moisture sensors. Short of on-site weather stations, users must settle for remote weather data, which may or may not be all that relevant to the site. One provides software at no cost, one charges $thousands.

The manufacturer's made their presentations, leaving Randy torn between two of the three. His preference was for a version of System B, but complemented with the soil moisture sensor capabilities of System A, for not too much more money. This led to the cost comparisons which Water Balance provided to Randy. The rest of the engineer's estimate is not shown.

PRINCIPAL CENTRAL CONTROL PARTS	System A		System B	
CONTROLLER(s)	$	2,620	$	2,234
RCV DECODERS FOR 52 TO 60 VALVES	$	2,207	$	4,583
SM SENSORS	$	4,428	n/a	
COMPUTER	$	1,441	$	1,419
SOFTWARE	$	131	$	5,450
FLOW SENSOR DECODER(s)	$	1,048	$	449
WIRE	$	5,568	$	2,619
SALES TAX	$	1,404	$	1,516
TOTAL	**$**	**18,847**	**$**	**18,270**

As one can see, the acquisition costs would be about equal. One system would depend on weather station data from AZ State University, some 6.5 miles away[1]. Life-cycle cost analysis would be offered later by Water Balance, if Randy desired it.

[1] The weather data is manipulated, and then factored some more to tell the computer how much soil moisture had been depleted over some period of time. It could be argued that System A was directly measuring soil moisture depletion from over 40 places right there at ASSA.

Soil Moisture Monitoring and Irrigation Frequency

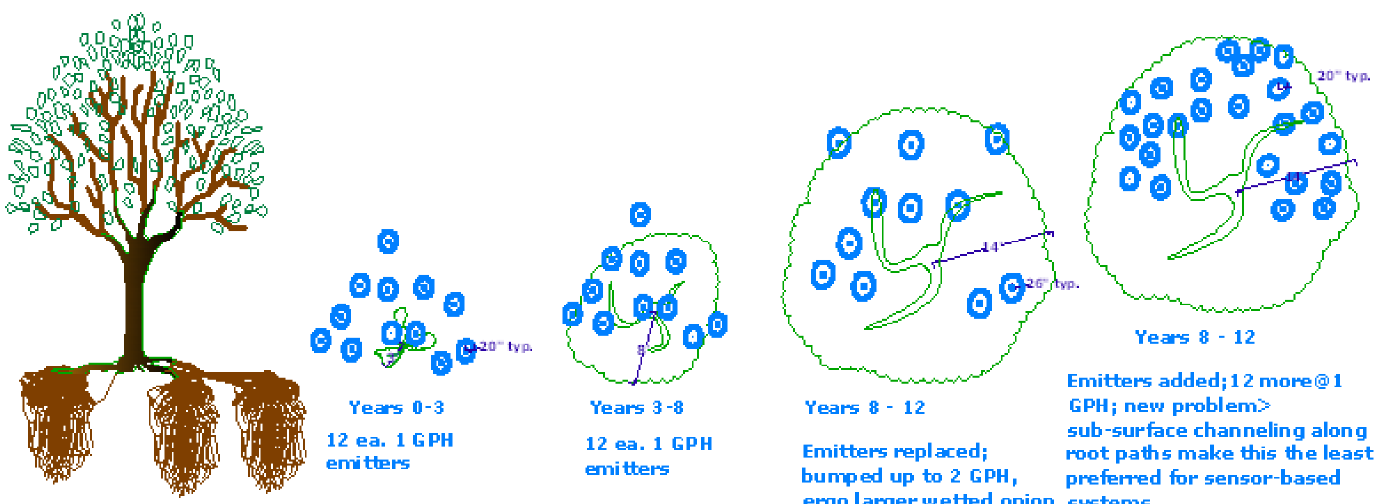
Since about 2001, Water Balance has promoted a practical approach to water management, in response and contrary to a few publications; one particular recommendation others hold to pertains to irrigation frequency when systems are low flow systems, as it is the case for shrubs and trees found across most of Arizona, Southern Nevada, and much of New Mexico. This recommendation suggests that drip irrigation systems can be left off for 7 days to 2 weeks during the growing season, which is supposed to encourage deeper roots. But this does not square with certified irrigation designers, especially designers with extensive experience in root-zone management. To apply 7 days supply, not to mention 10 to 14 days of supply, would require systems to run for over 35 hours continuously. Such systems only apply 24 gallons per hour!

One publication in particular, in 10 miniature pages, specifies how to design and manage irrigation systems for all of the typical plants used in landscaping, all the soil types and soil chemistries, throughout their entire, unique life-cycles, many from a spindly collection twigs to a gorgeous, 30’ tall X 30’ wide monster of a tree.

A model was developed by Water Balance after 6 years of service as the AZ DOT, Roadside Development Section, Irrigation Designer and Technical Leader. It is supposed to be self-explanatory. (See Appendix A)

Landscape irrigation using drip irrigation can be defined as high-frequency, low-volume irrigation which wets only a fraction of the plant canopy, and virtually none of the landscaped area without any plant canopy or cover. Unlike agricultural drip irrigation of row crops where over 60% of the planted acres are usually wetted, trees, shrubs and vines under drip, whether on the farm or at the community park may only have 30% to 50% of their canopy areas wetted, and less than 15% of the entire landscape wetted. What this means is that root-zones are much more compact. There are many more roots per cubic foot below emitters of a properly designed drip system, than in a cubic foot of same species, same bio-mass production, under sprinkler irrigation, where every square foot of the entire landscape receives a uniform depth of water. This is a very good thing, according to some, because the roots are more efficient, and they suspect that certain beneficial effects arise from very dense root zones.

The term “wetted onion” has been used to describe the shape of the wetted areas below each emitter.



Canopy Area Based Demand Increase (%)		610%	206%	206%
Conventional Pre-cipitation Rate	0.2 X 96.3/105.6 = 0.18 inches per hour	0.2 X 96.3/105.6 = 0.18 inches per hour	0.4 gpm X 96.3/177 s.f = 0.22 inches per hour	0.4 gpm X 96.3/211 s.f = 0.18 inches per hour
Application Rate	12/0.623/28.3 = 0.68 inches applied in one hour	12/0.623/201 = 0.10 inches applied in one hour	24/0.623/615 = 0.06 inches applied in one hour	24/0.623/615 = 0.06 inches applied in one hour
Percent Canopy Area Wetted	((1.67*1.67)*3.14)*12)/(3*3*3.14) = 370%	((1.67*1.67)*3.14)*12)/(8*8*3.14) = 52%	((2.17*2.17)*3.14)*12)/(14*14*3.14) = 29%	((1.67*1.67)*3.14)*24)/(14*14*3.14) = 34%

Determining Statistically Adequate Numbers of Soil Moisture Sensors Based Upon Soil Water Characteristics

One of the design considerations in implementation of a soil moisture-based irrigation control system is determining how many sensors will be required. There are situations where one sensor could be perfectly adequate for many acres. Describing how this could be true helps make a fundamental point. In order for one sensor to be sufficient, two different scenarios are described.

The first case applies to ADOT freeway landscaping. At ADOT, freeway embankments and slopes are always plated with 12" of topsoil. The soil may be moved from its first location, to a stockpile, and then moved to a final location along the freeway. In this process, the soils tend to get rather well mixed, and therefore homogenous. If the soils along one side or one mile of freeway were subsequently laid down uniformly compacted (as the specification requires), one sensor could be proven to be quite adequate for the entire 15 or so acres.

The second scenario recognizes that when soils are not extremely variable, one location still exists that is most representative, and probably considered the average soil, with respect to water holding and release capacity. The question is, how do you find this location? Imagine the same one-mile segment, a north-bound side of the freeway (a western exposure). By laying out a few 800' transect lines, and collecting soil samples from staked positions along these transects at say, 100 foot intervals, and determining the saturation percentage of the first foot and second foot (0" – 12", 12" – 24"), the results would likely help point to where the most average soil lay. In this way, saturation percentage is a very useful soil characteristic.

Of course such steps or circumstances steps are useful, but they only help to begin the process to insure reliability in the soil moisture-based control system. Water Balance recommends a sufficient number of sensors to insure reasonable probability that decisions are sound, and akin to "taking Ownership." The best way to do this on a new site is to install several more sensors than the saturation tests suggest, and then let the sensors, at equilibrium, prove the point that probably some sensors are not truly adding any new confidence or certainty to the irrigation scheduling process, and may be better used elsewhere. A little redundancy will always be beneficial.

Each SP determination, 2 recommended per grid space, cost $35.00, including the labor to collect, GPS mapping, statistically analyze and report. Total costs for this task was $2,800.00 (100' X 100' sample grid).

Questions and Problems / Opportunities

- Two-wire systems feature a) data communication to a decoder device located new the remote control valve, b) data shares the path with other valves, without conflict, because the data-packet is wrapped up in a unique address "folder", c) allows additions of valves, and expansion of systems (within limits) without running hardly any more wire, and d) save lots and lots of money normally paid for much more copper wire in the trench. Besides the cost of the modifications, what could be a negative aspect of a single two-wire pair running out to 40 or fifty valves, along a 3,000 foot long path?
- Why would Randy settle for System B, which uses weather station data, even though it is remote, and not entirely wrong all the time? Why, after over 30 years of various soil moisture measurement systems available commercially, would we start to find somewhat greater acceptance of soil moisture monitoring technologies and systems on golf courses today?
- If water cost alone is the justification for what is looking to be a $50,000 investment in new technology (installed and operator trained) at ASSA, and water application depths per year (site-wide, 5-year average) over the 10 acre campus are 79 inches per year, when a reasonable, average annual "water requirement" is but 57 inches per year, granting that annual rainfall takes abundant care of the leaching of salts, and the water currently costs ASSA $490.00 per acre foot, how long will it take to pay-back the investment? What other matters need consideration?
- Some contend that economic benefits to producers and facility managers for adoption of better decision support systems on farms and facilities are barely sufficient to adopt new technology, and perhaps requires that they hire more technically capable staff to operate those systems. They have said that often the benefits accrue to the larger community, rather than directly to the party that takes out the loan, and bears the risk of something new. What should happen at the City, State, County, Federal, International levels to help them take steps that conserve, protect, and restore natural habitats or resources?

APPENDIX A.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total	
ADWR WATER BUDGET (LWU-LA)	0.25	0.25	0.5	1	3	4	4	3	1	0.5	0.25	0.25	18	Gross Inches
CANOPY AREA (75%) BUDGET	0.5	0.5	1	1	4	5	5	4	1	1	0.5	0.5	24	Gross Inches

Note: ADWR requires industrial water users confine water use in low water use (LWU) to 18" (gross) per year per landscapeable acre (LA)

Diameter	Canopy Area SF		GALS. PER PEAK MONTH		GALS. PER PEAK DAY
10	79	In. per Mo. X 0.623 X Canopy Area =	245	In. per Day. X 0.623 X Canopy Area =	8

Note: The most common approach in irrigation design and system management is to account for system and management efficiencies AFTER establishing the NET, plant water demands.
In this exercise, like ADWR, Irrigation Efficiency and Application Efficiency are not separately accounted for. The rest of this example conforms to this precept, and
it is accepted that though the peak use per day for a desert adapted may be lower, roughly 7/8ths of the trees will be over-irrigated; 51 gallons per day provides gross deliveries, not net DEMANDS.

Water Holding Capacity of Various Soils As Affected by Soil Water Salinity

Inches Avail Water per Inch of soil Depth (

Texture Class	Soil solution Ece 4	8
Silty clay	0.15	0.12
Clay loam	0.18	0.15
Loam	0.16	0.13
Sandy loam	0.11	0.09

MANAGEMENT ALLOWED SOIL MOISTURE DEPLETION AND IRRIGATION FREQUENCY

SPARSELY PLANTED, DESERT ADAPTED TREES;

1) MICRO-SPRINKLER -->>	100%	Wetted Area
2) MANY EMITTERS -->>	60%	Wetted Area
3) FEW EMITTERS --------->>	30%	Wetted Area

Givens:

Active Root Depth (inches)	28
Average Soil Type	Clay loam
Soil Solution Elec. Conduct'y. (mS/cm)	8
Management Efficiency	0.95
Distribution Uniformity	0.82

WATER STORED WITH EACH IRRIGATION UNDER AND AROUND INDIVIDUAL TREES (GALLONS)

************* SOIL MOISTURE RANGE ***********

WETTED AREA	from:	FULL (0% DEPLETED) TO 50% DEPLETED	FROM 25% DEPLETED TO 50% DEPLETED
100%		103	51
60%		62	31
30%		31	15

IRRIGATION FREQUENCY (Days between irrigation; Storage Divided by Peak, Daily Alloted Volume Minus Losses)

************* SOIL MOISTURE RANGE ***********

WETTED AREA	from:	FULL (0% DEPLETED) TO 50% DEPLETED	FROM 25% DEPLETED TO 50% DEPLETED
100%		9.8	4.9
60%		5.9	2.9
30%		2.9	1.5

Note: To accomplish the "75% - 50% depletion" you must manage system to pulse irrigation, thereby pushing water to RZ boundary.
Additionally: Through 8 gallons are allocated per peak day, per 10 foot tree, regardless of species, 8 gallons per day are not stored.
Therefore, irrigation frequencies must increase to account for the water that is not stored. If 8 gallons were stored, irrigation efficiency would be 100%.
Finally, the micro-sprinkler systems usually can not maintain soil moistures below 100% like drip irrigation delivered to the center of "wetted onions."