Aspect
CONSULTING

MEMORANDUM

Project No.: 190286

September 26, 2019

To: Tod Heisler, Central Oregon LandWatch

From:

REGISTERED PROFESSIONAL ENGINEER
16,314
OREGON
DEC. 1, 1992
JOHN S. WARINNER

September 26, 2019

John S. Warinner, PE, CWRE
Associate Water Resources Engineer
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Re: **COID Water Efficiency**
Private Laterals

Purpose

In June 2019, Central Oregon LandWatch (COLW) engaged Aspect Consulting, LLC (Aspect) to perform an engineering analysis and deliver a technical memorandum that answers the following questions posed by COLW pertaining to the Central Oregon Irrigation District (COID):

> *Q1. Within the Pilot Butte system of canals and laterals, and starting at the most downstream points in the private laterals, how far upstream would one need to pipe in order to generate sufficient pressure to operate: (a) center pivot, (b) wheel line, and (c) K-Line?*

> *Q2. What is the estimated cost to install piping to this extent?*

To inform this analysis, COLW provided Aspect with a copy of a sample rotation schedule for COID Rotation 10500 (Headgate B-11-8), which is attached as Appendix 1 and an On-Farm Water Conservation Report prepared by Black Rock Consulting and Farmers Conservation Alliance for which a relevant excerpt is included as Appendix 2.

Midway through the analysis, Aspect shared some preliminary findings with COLW. In response to these preliminary findings, COLW amended the guiding questions to include the following:

> *Q3. Estimate the cost of piping all 300 private rotations in COID?*

Q4. Estimate the cost of piping the district-owned sub-laterals up to but not including the primary laterals?

Q5. Estimate the water conserved, seepage losses reclaimed?

This memorandum represents the deliverable product for this initial phase of work.

Two figures help clarify the answers we have developed to the questions posed by COLW. Figure 1 presents a map of the sample rotation area and the conceptual layout of the pipeline proposed to replace the private lateral within the sample rotation. Figure 2 presents a map of the COID canal system upstream of the sample rotation area and degrees to which the private lateral pipeline must be extended to generate various operating pressures at the headgate serving this private lateral.

Results

This section presents concise answers to the five questions posed by COLW. Supplementary details are provided in following section of this memorandum.

Q1. Within the Pilot Butte system of canals and laterals, and starting at the most downstream points in the private laterals, how far upstream would one need to pipe in order to generate sufficient pressure to operate: (a) center pivot, (b) wheel line, and (c) K-Line?

The minimum pressure required to operate the most energy-efficient configurations of the three specified irrigation systems is about 30 pounds per square inch (psi). To deliver 30 psi to the headgate serving the sample rotation, one would need to pipe the COID system about 6,600 feet (ft) (1.25 miles) upstream of the headgate. As illustrated in Figure 2, this location is approximately where the COID sub-lateral crosses the McKenzie Highway connecting Redmond to Sisters.

The pressure required to operate all possible configurations of the three specified irrigation systems is about 60 psi. To deliver 60 psi to the headgate serving the sample rotation, one would need to pipe the COID system about 16,500 ft (3.1 miles) upstream of the headgate. As illustrated in Figure 2, this location is approximately 2,000 ft north of where the COID sub-lateral crosses SW Wickiup Avenue.

An alternative to extending the pipeline upstream to this extent would be to install a pump station at the headgate (upstream end of the private lateral) to locally pressurize the private lateral system. If piping of the upstream district lateral was anticipated or planned, a package booster pump station could be installed to locally pressurize the private lateral system on a temporary basis until the upstream district lateral was constructed. Aspect mentioned this alternative to COLW but did not analyze or estimate the cost of this alternative approach. COLW indicated that COID was investigating this alternative to some degree.

Additional details are provided in the Details Section of this memorandum under the headings Pressure Required to Operate Specified Irrigation Systems and Upstream Distance to Pipe to Generate Sufficient Operating Pressure.

Q2. What is the estimated cost to install piping to this extent?

The cost to construct a buried pipeline to fully replace the private lateral ditch is estimated at $150,833. This cost estimate includes a water delivery manifold at each water delivery point within the rotation that includes a control valve and flowmeter. This cost estimate also includes markups for engineering (15 percent), construction management (18 percent) and contingency (30 percent) to provide a conservative estimate of uncertainties associated with this conceptual level of design. Aspect did not estimate the cost to extend the pipeline upstream from the private lateral headgate due to complexities and uncertainties regarding the quantity, size(s) and water demand(s) associated with the other private laterals that would also be served by this COID-owned lateral pipeline. This information exceeded the scope of this investigation.

Additional details are provided in the Details Section of this memorandum under the heading Estimated Cost to Construct the Private Lateral Pipeline.

Q3. Estimate the cost of piping all 300 private rotations in COID?

Aspect estimated a cost of $33,832,000 to pipe all 300 private rotations.

This estimate was based on extrapolation of the $150,833 estimated for the sample rotation which included 5,885 linear feet (LF) of pipe to the 250-mile total length of private laterals estimated by Black Rock and FCA in Appendix 2.

Additional details are provided in the Details Section of this memorandum under the heading Estimated Cost to Pipe All 300 Private Rotations in COID.

Q4. Estimate the cost of piping the district-owned sub-laterals up to but not including the primary laterals?

Aspect did not estimate the cost of piping the district-owned sub-laterals up to, but not including, the primary laterals. As noted in the answer to Q2 above, estimating costs to pipe the district-owned sub-laterals upstream of the private lateral headgates requires information regarding the locations and water demands at each of the other headgates served by the sub-lateral. Unfortunately, this information is not readily and publicly available, so Aspect considers this question to exceed the scope of this initial investigation.

Q5. Estimate the water conserved, seepage losses reclaimed?

Aspect estimated that piping the private lateral ditches within all 300 private rotations within COID could potentially conserve 2.5-to-3.0 acre-feet of water per acre per year, for a total of 57,000-to-68,000 acre-feet-per-year for the 22,712 acres currently served by private laterals.

In summary, the total cost of $33,832,000 to conserve 57-to-68,000 acre-feet-per-year suggests a capital cost of about $500-600 per acre-foot of annual water savings.

Additional details are provided in the Details Section of this memorandum under the heading Estimate of Water Conserved and Seepage Loss.

Details

This section presents the analyses informing the results summarized in the preceding Results section of this memorandum.

Pressure Required to Operate Specified Irrigation Systems

Recommended operating pressures for the three specified types of agricultural irrigation systems vary widely, depending on choices made regarding sprinkler makes and models and nozzle types.

For each of the identified types of sprinkler systems, Aspect researched product literature from the following websites:

- **Center Pivot**
  - Researched product literature for Nelson Irrigation Corporation center pivot products at www.nelsonirrigation.com. Nelson is a primary supplier to all the major center pivot manufacturers and holds a significant market share for center pivot sprinklers in the global market. Attached as Appendix 3.
- **Wheel Line**
  - Researched product literature for the Wade Rain Poweroll products at www.waderain.com. Wade Rain is a primary manufacturer of wheel line irrigation systems in Oregon and beyond. Attached as Appendix 4.
- **K-Line**
  - Researched product literature for the K-Line irrigation system at www.k-linena.com. K-Line Irrigation North America is the manufacturer and distributor of K-Line irrigation systems. Attached as Appendix 5.

Product literature published by these selected irrigation equipment manufacturers suggests the following ranges of recommended operating pressures:

- Center Pivot: 6 to 60 psi, depending on the selected sprinkler, plate and nozzle
- Wheel Line: 30 to 50 psi, depending on the selected sprinkler configuration
- K-Line: 35 to 60 psi, depending on the selected sprinkler configuration

Based on the product manufacturers' literature, the minimum pressure required to operate the most energy-efficient configurations of the three specified irrigation systems is about 30 psi. The pressure required to operate all possible configurations of the three specified irrigation systems is about 60 psi.

Upstream Distance to Pipe to Generate Sufficient Operating Pressure

The first step in estimating the upstream distance required to pipe the sample private lateral involved mapping the private lateral, conceptual pipeline, and the COID lateral system serving the sample private lateral.

Aspect used the Deschutes County website to identify and tabulate the individual land parcels (tax lots) referenced in the sample rotation schedule. Aspect then used publicly available Deschutes

County land parcel data and LiDAR data from the Oregon Department of Geology and Mineral Industries (DOGAMI) to map and characterize the COID canals and laterals, and private laterals, delivering water to the land parcels referenced in the sample rotation schedule.

Aspect used this information to determine approximate locations and elevations for the water delivery points for each of the properties in the sample rotation. The conceptual layout of the proposed pipeline is illustrated in Figure 1.

The pressure generated by piping is driven by the elevation gained over the length of the pipe. So to generate a given pressure at the headgate, the supply pipeline must be extended upstream until it reaches the elevation that results in an associated positive head pressure at the headgate. Each 1 psi of pressure requires 2.31 feet of head or elevation gain. So generating 30 psi of operating pressure at the headgate requires about 70 feet of elevation gain. Similarly, 60 psi of operating pressure at the headgate requires about 140 feet of elevation gain.

For the sample rotation, the headgate is located at an elevation of about 2,920 feet (Point A15 in Figure 2). Since 70 feet of elevation gain are required to generate 30 psi, the pipeline must be extended to an elevation of 2990 feet. This location corresponds to the location where the COID sub-lateral crosses the McKenzie Highway connecting Redmond to Sisters (Point A18). So, to generate the minimum pressure required to operate the most energy-efficient configurations of the three specified irrigation systems (about 30 psi), one would need to pipe the COID system about 6,600 ft (1.25 miles) upstream of the headgate serving the sample rotation.

Since 140 feet of elevation gain required to generate 60 psi at the headgate, the pipeline must be extended to an elevation of 3,060 feet. As illustrated in Figure 2, this location is approximately 2,000 feet north of where the COID sub-lateral crosses SW Wickiup Avenue (Point A19). So, to generate adequate pressure to operate all possible configurations of the three specified irrigation systems (about 60 psi), one would need to pipe the COID system about 16,500 ft (3.1 miles) upstream of the headgate serving the sample rotation.

Conceptual Design of Private Lateral Pipeline

The first step in estimating the cost to pipe the private lateral was to layout and determine the appropriate sizes of the pipeline. This process included the following steps:

- Identify approximate delivery points for each water user served by the private lateral ditch
- Determine the most cost-effective and convenient alignment of the pipelines serving each point of delivery
- Determine the assumed timing and duration of water delivery to each delivery point
- Estimate the rate at which water must be delivered to each delivery point
- Determine the size of the pipe(s) required to deliver water to each delivery point on the assumed water delivery schedule

The conceptual layout of the proposed pipeline is illustrated in Figure 1.

Points of Delivery

Based on the sample rotation provided to Aspect by COLW, Aspect assumed that each property owner served by the private lateral has a unique and independent point of delivery. In a few cases, it was evident that more than one land parcel was owned and irrigated by a common landowner. This was typically two adjacent land parcels. In these cases, Aspect assumed that both land parcels may be served by a common water delivery point. Aspect mapped the assumed location of water delivery points based on careful inspection of aerial imagery, including both color photography and LiDAR-generated mapping of land surface elevations (topography). The resulting water delivery points and their corresponding elevations are summarized in Table 1.

Pipeline Alignment

Aspect assumed that the most cost-effective and convenient approach would be to install the proposed pipeline utilizing the current alignment of the existing private lateral ditch. Aspect mapped the assumed alignment of the existing ditch based on careful inspection of aerial imagery, including both color photography and LiDAR-generated mapping of land surface elevations (topography) to connect the pipeline to the assumed water delivery points.

Timing and Duration of Water Delivery

The existing weekly rotation schedule for the sample rotation (Appendix 1) is constructed around an assumption that COID continuously delivers water to the private lateral and each water user has a specific assigned day and duration during which they are scheduled to receive the full flow delivered by COID to the private lateral. Each week, each water user receives their water during this prescribed time interval, and either directly applies it to their irrigated lands upon delivery, or stores it in an on-farm pond, and then applies it to their irrigated lands over the course of the week.

For this analysis, Aspect assumed a different operational scenario. Based on consultation with COLW, Aspect assumed that the private lateral pipeline would be designed to make water available to all users on a continuous basis (for use at any time during the week), but only at the pro rata rate considered sufficient to irrigate the crop with the highest rate of consumptive water use typically grown in COID. This rate of water delivery is addressed in the following section.

It is important to note that this operational scenario <u>is predicated on the assumption that the entire water delivery system is closed and/or includes ample storage</u> so that COID has a means to store "surplus" water during periods of time when some water users are receiving less than their full water allotment. This operational scenario resembles a typical municipal water system.

Rate of Water Delivery

As presented above, Aspect assumed that the proposed pipeline will deliver water on a continuous basis (for use at any time throughout the week) at the pro rata rate considered sufficient to irrigate the crop with the highest rate of consumptive water use typically grown in COID. Table 2 summarizes the net and gross water demands for the two most common crops grown in COID (grass pasture and alfalfa hay) published by Oregon State University in *Oregon Crop Water Use and Irrigation Requirements*.[1] An excerpt from this publication is attached as Appendix 6.

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[1] https://catalog.extension.oregonstate.edu/sites/catalog/files/project/pdf/em8530.pdf

Table 1. Water Delivery Points for Piping of Private Lateral for Sample Rotation

Point ID	Estimated Elevation (feet)	Irrigated Acres (acres)	Maximum Demand (gpm)
A1	2887	1.0	8.0
A2	2887	1.0	8.0
A3	2888	2.0	16.0
A4	2892	3.6	28.8
A5	2899	2.0	16.0
A6	2911	2.0	16.0
A7	2912	4.0	32.0
A8	2914	1.2	9.6
A9	2915	1.2	9.6
B1	2877	2.0	16.0
B2	2882	1.5	12.0
B3	2886	0.7	5.6
B4	2892	2.0	16.0
AB	2916	N/A	N/A
A10	2916	1.5	12.0
A11	2917	2.7	21.6
A12	2917	1.7	13.6
A13	2917	2.0	16.0
A14	2918	2.0	16.0
A15	2920	N/A	N/A

Table 2. Water Demands for Common Agricultural Crops in COID

	PASTURE (Growing Season Apr 12 – Oct 24)		ALFALFA HAY (Growing Season Apr 10 – Oct 1)	
MONTH	NET IRRIG (inches)	GROSS IRRIG (inches)	NET IRRIG (inches)	GROSS IRRIG (inches)
APR	2.40	3.20	2.44	3.25
MAY	4.80	6.40	4.49	5.99
JUN	5.98	7.97	5.63	7.51
JUL	7.36	9.81	6.89	9.19
AUG	6.14	8.19	5.75	7.67
SEP	4.37	5.83	4.09	5.45
OCT	2.24	2.99	N/A	0.00
TOTAL (in)	**33.29**	**44.39**	**29.29**	**39.05**
TOTAL (ft)	**2.77**	**3.70**	**2.44**	**3.25**

The gross irrigation demands summarized in Table 2 assume that water users would apply the water with one of the three specified irrigation methods (center pivot, wheel line or K-Line), assuming a water application efficiency of these systems is estimated to be 75 percent. Solid set sprinklers are considered equivalent to wheel line and/or K-Line irrigation systems.

The crop water demands summarized in Table 2 suggest that grass pasture has the highest water demand. So, water delivery systems should be designed to accommodate the demands of this crop. The peak rate of water demand is the 9.81 inches of water required in July, which equates to a peak gross demand of 0.32 inch per day. Through unit conversion this value can be converted to a peak rate of 6.0 gallons per minute per acre (gpm/ac).

For the conceptual design of the private lateral pipeline, Aspect assumed a water delivery rate of 8.0 gallons per minute per acre (gpm/ac), to incorporate a factor of safety or contingency at this conceptual design level, and maintain some degree of consistency and comparability with the *Central Oregon Irrigation District On-Farm Water Conservation Report* in Appendix 2.

The rate of water delivery to each water delivery point was computed by multiplying this pro rata rate by the acreage of the authorized place of use. For example, for a property with an authorized place of use of 1.0 acre, water will be delivered at a maximum rate of 8.0 gpm. For a 2.0-acre authorized place of use, water will be delivered at a maximum rate of 16.0 gpm. The water delivery rates for each delivery point were summarized in Table 1.

Pipe Sizing

For this analysis, Aspect sized the pipeline segments to deliver water to all water users at their maximum rate while maintaining relatively low flow velocities in the pipeline on the order of 2-to-3 feet per second (fps). Since general design standards typically recommend that water delivery pipelines be designed for a maximum flow velocity of 5 fps, this design assumption results in a relatively conservative pipe sizing (conservatively large). This presents a potential opportunity for value engineering and cost savings during a later stage of preliminary and/or final engineering design. The resulting pipeline segments, lengths, maximum flows and sizes are summarized in Table 3.

Table 3. Conceptual Pipe Sizing of Private Lateral for Sample Rotation

Down Stream Node ID	Up Stream Node ID	Estimated Length (feet)	Maximum Discharge (gpm)	Pipe Diameter (inches)
A1	A3	200	8.0	2.0
A2	A3	300	8.0	2.0
A3	A4	500	32.0	3.0
A4	A5	200	60.8	3.0
A5	A6	600	76.8	4.0
A6	A7	100	92.8	4.0
A7	A8	200	124.8	6.0
A8	A9	200	134.4	6.0
A9	AB	450	144.0	6.0
B1	B2	330	16.0	2.0

B2	B3	430	28.0	3.0
B3	B4	400	33.6	3.0
B4	AB	400	49.6	3.0
AB	A10	100	193.6	6.0
A10	A11	400	205.6	6.0
A11	A12	100	227.2	8.0
A12	A13	75	240.8	8.0
A13	A14	200	256.8	8.0
A14	A15	700	272.8	8.0
TOTAL		**5,885**		

Estimated Cost to Construct Private Lateral Pipeline

Aspect estimated the cost to construct the private lateral pipeline based on the following assumptions:

1. Pipe materials considered both polyvinyl chloride (PVC) and high-density polyethylene (HDPE)

2. Pipe installation included trench excavation, pipe bedding, pipe assembly, pressure testing, and trench backfill.

3. Pipe materials included a water delivery manifold at each water delivery point served by the private lateral ditch/pipe, including a manual control valve and flowmeter.

4. Aspect considered including a passive intake screen at the headgate to each private lateral to prevent debris in the COID lateral canal from entering the private lateral pipeline. However, this item was excluded based on the assumption that the upstream laterals operated by COID would also be piped or this item could be included in the contingency.

5. This cost estimate includes markups for engineering (15 percent), construction management (18 percent) and contingency (30 percent), to provide a conservative estimate given the uncertainties associated with this conceptual level of design.

6. Unit costs for raw pipe and installation are summarized in Table 4.

Table 4. Unit Costs for Pipeline Materials and Installation

Pipe Size (inches)	HPDE Pipe Cost ($/LF)	HPDE Installation ($/LF)	HPDE Total Cost ($/LF)	PVC Pipe Cost ($/LF)	PVC Installation ($/LF)	PVC Total Cost ($/LF)
2	$0.59	$10.50	$11.09	$0.60	$9.90	$10.50
3	$0.89	$10.50	$11.39	$1.29	$9.90	$11.19
4	$1.25	$10.50	$11.75	$2.15	$9.90	$12.05
6	$1.73	$10.50	$12.23	$4.70	$9.90	$14.60
8	$3.03	$10.50	$13.53	$7.64	$9.90	$17.54

Estimated Cost to Pipe All 300 Private Rotations in COID

As presented in the previous section of this memorandum, Aspect developed several estimates of the cost of piping all 300 private rotations, based on various assumptions and scenarios.

The most representative and valuable estimate was based on extrapolation of the estimated cost of piping the sample rotation based on total length of the private lateral ditches served by COID.

The total length of private lateral ditches was estimated in the *Central Oregon Irrigation District On-Farm Water Conservation Report* (Appendix 2) as 250 miles, for the 22,712 acres in 300 rotations served by private laterals.

Aspect divided the sample rotation cost of $150,833 by 5,885 LF for a per-foot cost of $25.63, and then multiplied this quantity by 250 miles (with unit conversions) and rounded to the nearest thousand for a total of $33,832,000.

Estimate of Water Conserved and Seepage Losses Reclaimed

Aspect (with COLW) examined and estimated various forms of water loss and conservation potential based on two complementary analyses.

The first analysis estimated overall conveyance losses based on COID water delivery data referenced in an engineering report titled *Central Oregon Irrigation District On-Farm Water Conservation Report* (Appendix 2) and crop consumptive use and irrigation demands published in the *Oregon Crop Water Use and Irrigation Requirements* (Appendix 6).

According to a summary compiled by COLW, COID measured delivery of 88,242 gpm (197 cfs) to 10,646 acres for a rate of 8.29 gpm-per-acre and a total volume of 70,075 acre-feet. Dividing the volume of 70,075 acre-feet by 10,646 acres suggests a gross water delivery rate of 6.58 acre-feet per acre.

The data in Table 2 suggest that the gross irrigation rate for sprinkler-irrigated pasture is 44.4 inches or 3.7 acre-feet per acre. This value represents the rate at which water must be applied to satisfy both the consumptive use of the crop plus the loss due to evaporation associated with water application. Subtracting this rate from the gross water delivery rate of 6.58 acre-feet per acre suggests a total conveyance loss of 2.88 acre-feet per acre.

This total conveyance loss is understood to include both seepage and evaporation from delivery canals and ditches, as well as operational spills. The relative portions of the total loss attributable to seepage, evaporation and operational spills are unknown.

To estimate the portion attributable to seepage, Aspect performed a second analysis to estimate ditch seepage based on the physical characteristics of the private lateral ditch.

A publication by the United States Bureau of Reclamation (USBR) suggests that canal/ditch seepage can be calculated using the Moritz formula, as follows:

$$S = 0.2\ C\ (Q/V)^{1/2}$$

Where:

S = seepage loss in cfs per mile

Q = discharge in cfs

V = mean velocity of flow in feet-per-second (fps)

C = coefficient of the rate of water loss (cfs) in 24 hours through the wetted perimeter of the canal/ditch floor and walls

For this analysis, the private lateral ditch substrate was assumed to be "sandy soil with rock" with a C-value of 1.68. The ditch cross-section was assumed to be about 1.5 feet wide flowing 1.5 feet deep. The discharge was estimated for each reach of the private lateral at 8.0 gpm per acre for the total acreage of the rotation (34 acres). Each reach of the ditch was assumed to be flowing and seeping only during the time interval in the weekly rotation when one of the downstream water delivery points were being served. The duration of annual operation was estimated as 195 days per season, based on the duration of the growing season identified in *Oregon Crop Water Use and Irrigation Requirements*[2] (Appendix 6) published by Oregon State University. Aspect considered this to represent a relatively conservative estimate scenario.

Based on these assumptions, Aspect estimated seepage from the ditch to be 87.8 acre-feet per year. For the 34-acre rotation, this equates to 2.58 acre-feet per acre.

While the relative portions of the total loss attributable to seepage, evaporation and operational spills are unknown, this estimate suggests that seepage represents the primary component of the total conveyance loss for the private lateral ditches.

Integrating the two analyses suggests that piping the private lateral ditches within all 300 private rotations within COID could potentially conserve 2.5-to-3.0 acre-feet of water per acre per year. For the 22,712 acres served by private laterals, piping the private lateral ditches could conserve approximately 57,000-to-68,000 acre-feet-per-year.

Considerations

It is important to consider the overall hydrologic cycle and recognize that some "losses" due to seepage from canals and laterals are essentially "gains" or "inputs" to groundwater aquifers. Locations, timing and impacts associated with conservation strategies such as piping should be evaluated to quantify and understand the associated impacts to the quantity and quality of flows in groundwater aquifers and down-gradient streams. In situations where groundwater levels are declining, or subject to future decline as a result of piping canals and/or ditches, strategies should be considered to incorporate artificial groundwater recharge as an element of the system design.

[2] https://catalog.extension.oregonstate.edu/sites/catalog/files/project/pdf/em8530.pdf

Limitations

Work for this project was performed for Central Oregon LandWatch (Client), and this memorandum was prepared in accordance with generally accepted professional practices for the nature and conditions of work completed in the same or similar localities, at the time the work was performed. This memorandum does not represent a legal opinion. No other warranty, expressed or implied, is made.

All reports prepared by Aspect Consulting for the Client apply only to the services described in the Agreement(s) with the Client. Any use or reuse by any party other than the Client is at the sole risk of that party, and without liability to Aspect Consulting. Aspect Consulting's original files/reports shall govern in the event of any dispute regarding the content of electronic documents furnished to others.

Attachments:
Figure 1 – Conceptual Layout of Piping for Sample Rotation
Figure 2 – Conceptual Upstream Extension of Lateral Piping
Appendix 1– Rotation schedule for COID Rotation 10500 (Headgate B-11-8)
Appendix 2 – On-Farm Water Conservation Report (excerpt)
Appendix 3 – Product literature for Nelson Irrigation center pivot products
Appendix 4 – Product literature for the Wade Rain Poweroll products
Appendix 5 – Product literature for the K-Line irrigation system
Appendix 6 – Oregon Crop Water Use and Irrigation Requirements (excerpt)

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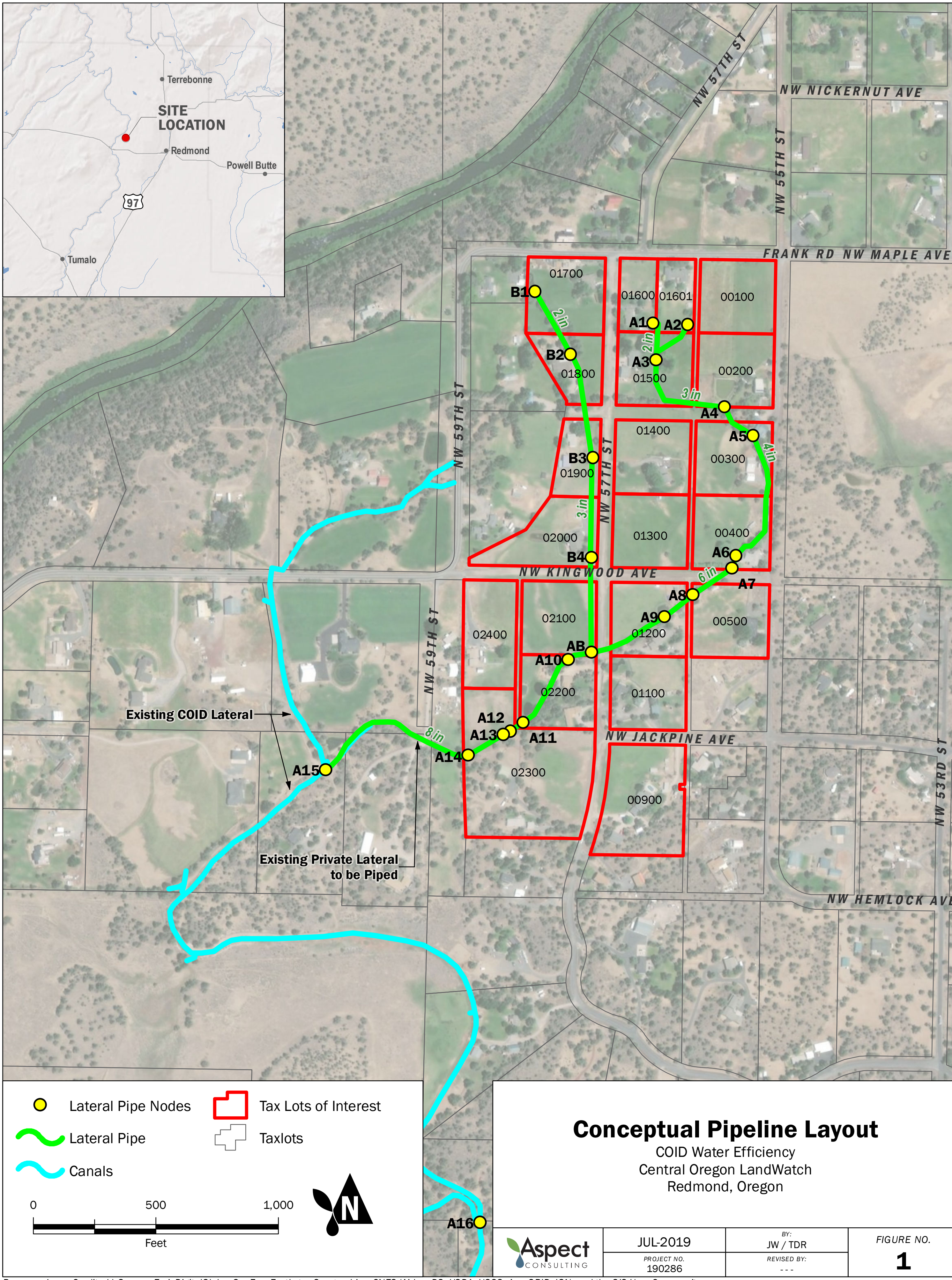
FIGURES



Conceptual Pipeline Layout

COID Water Efficiency
Central Oregon LandWatch
Redmond, Oregon

Aspect CONSULTING	JUL-2019	BY: JW / TDR	FIGURE NO. 1
	PROJECT NO. 190286	REVISED BY: - - -	

Basemap Layer Credits || Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
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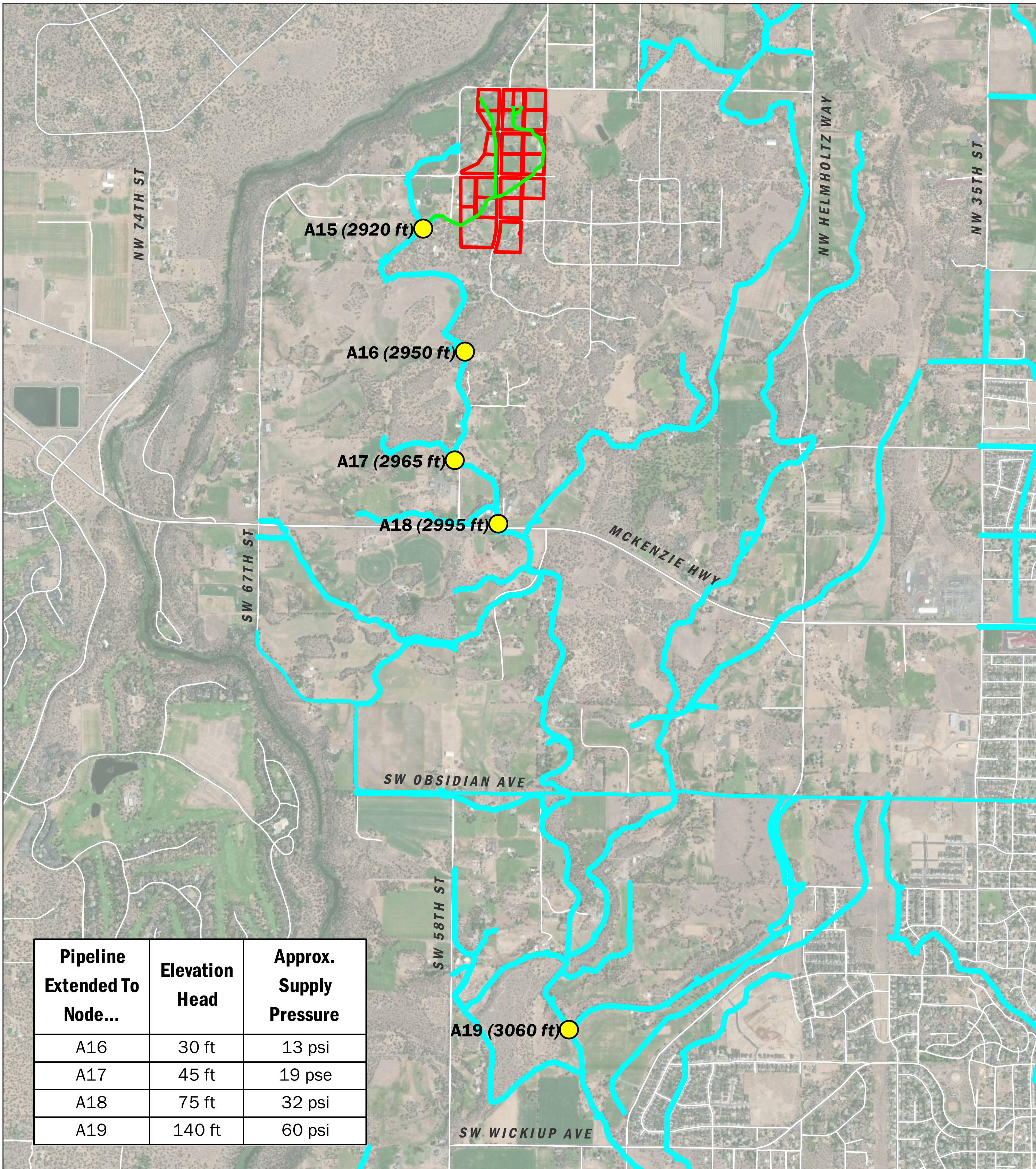
GIS Path: T:\projects_8\COIDWaterEfficiency_190286\Delivered\01 Conceptual Pipeline Layout.mxd || Coordinate System: NAD 1983 StatePlane Oregon North FIPS 3601 Feet || Date Saved: 7/12/2019 || User: trullen || Print Date: 7/12/2019



Pipeline Extended To Node...	Elevation Head	Approx. Supply Pressure
A16	30 ft	13 psi
A17	45 ft	19 pse
A18	75 ft	32 psi
A19	140 ft	60 psi

GIS Path: T:\projects_8\COIDWaterEfficiency_190286\Delivered\02 Conceptual Pipeline Extension.mxd || Coordinate System: NAD 1983 StatePlane Oregon North FIPS 3601 Feet || Date Saved: 7/12/2019 || User: trullen || Print Date: 7/12/2019

Conceptual Pipeline Extension

COID Water Efficiency
Central Oregon LandWatch
Redmond, Oregon

Aspect CONSULTING	JUL-2019	BY: JW / TDR	FIGURE NO.
	PROJECT NO. 190286	REVISED BY: - - -	2

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Appendix 1

Rotation schedule for COID Rotation 10500 (Headgate B-11-8)

Rotation Id: 10500

Patrolman: John Hargrove

Beat: Pilot Butte Canal Beat No 2

2016 Rotation Schedule

Acreage: 34.100

Phone: 548-6047

7 Day Rotation

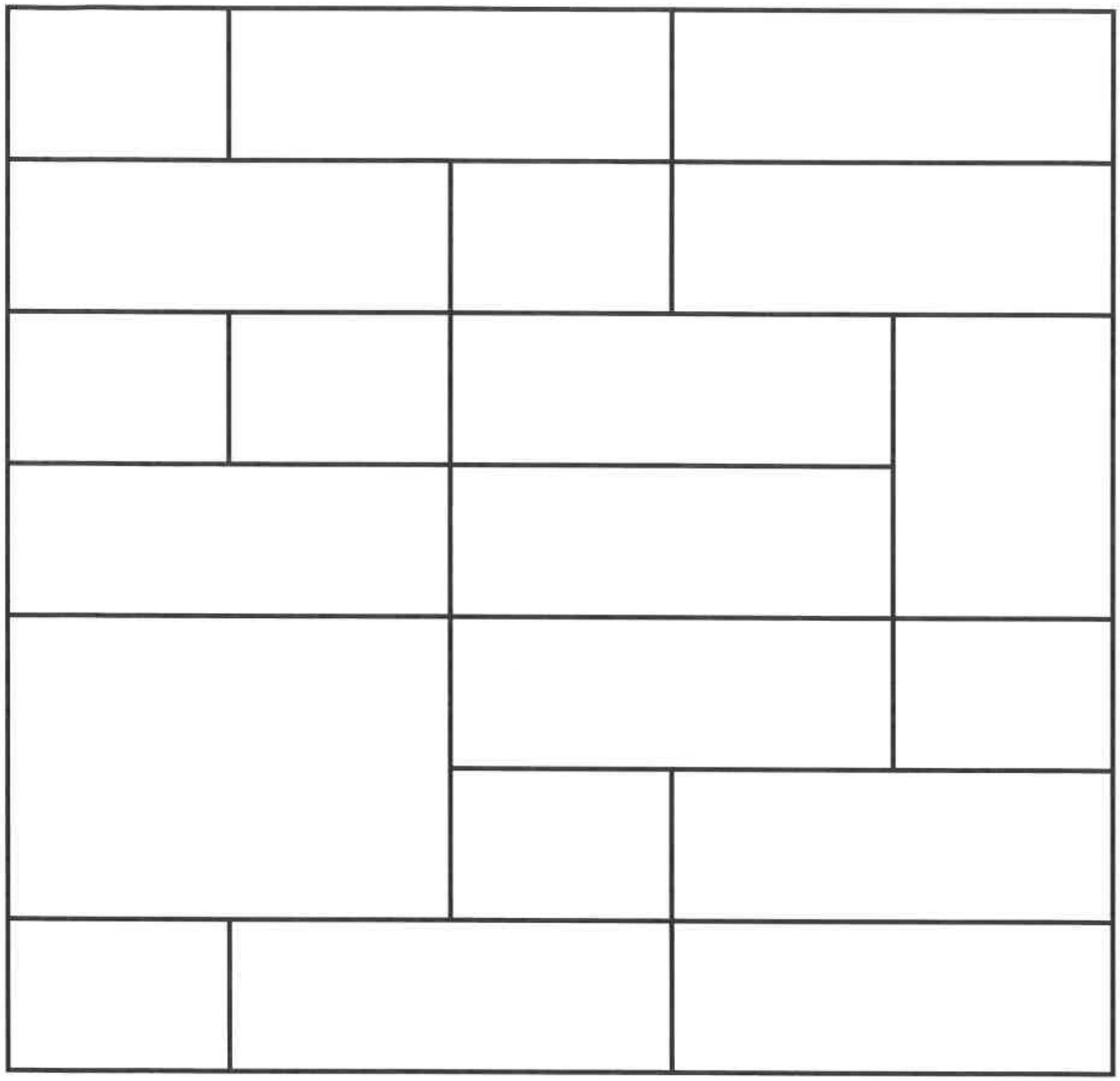
Participating Headgates:

B-11-8

	Patrons	**Acreage**	**Days**	**Hours**	**Min**	**Scheduled Time**				
1	Clark, Jeffrey R/Leslie	1.000	0	4	56	Sun	7:00 am	to	Sun	11:56 am
2	Richardson, Patricia	2.000	0	9	51	Sun	11:56 am	to	Sun	9:47 pm
3	Turpen, Kevin/Heidi	1.700	0	8	23	Sun	9:47 pm	to	Mon	6:10 am
4	Clark, Jeffrey R/Leslie	2.000	0	9	51	Mon	6:10 am	to	Mon	4:01 pm
5	Brown, Paasche/Levi	1.500	0	7	23	Mon	4:01 pm	to	Mon	11:24 pm
6	Colvin, Gregory/Lorraine	1.700	0	8	23	Mon	11:24 pm	to	Tue	7:47 am
7	Deleone, Robin M	1.200	0	5	55	Tue	7:47 am	to	Tue	1:42 pm
8	Keller, Jerry S/Ruth	1.200	0	5	55	Tue	1:42 pm	to	Tue	7:37 pm
9	Blakley, Daniel R/Sandra	2.000	0	9	51	Tue	7:37 pm	to	Wed	5:28 am
10	Stern, Matthew	2.000	0	9	51	Wed	5:28 am	to	Wed	3:19 pm
11	May, Diane N.	2.000	0	9	51	Wed	3:19 pm	to	Thu	1:10 am
12	Peplin, Todd M	2.000	0	9	51	Thu	1:10 am	to	Thu	11:01 am
13	Fullman, Harold/Marilyn	3.600	0	17	44	Thu	11:01 am	to	Fri	4:45 am
14	McKenzie, Timothy/Mary Sue	2.000	0	9	51	Fri	4:45 am	to	Fri	2:36 pm
15	Hitson, Benjemen	1.000	0	4	56	Fri	2:36 pm	to	Fri	7:32 pm
16	Hayward, Terry Lee/Kelly	1.000	0	4	56	Fri	7:32 pm	to	Sat	12:28 am
17	Tanler, Cheryl L.	2.000	0	9	51	Sat	12:28 am	to	Sat	10:19 am
18	Hawkins, Janice	0.700	0	3	27	Sat	10:19 am	to	Sat	1:46 pm
19	Davidson, Don G/Mary	1.500	0	7	23	Sat	1:46 pm	to	Sat	9:09 pm
20	McCoy, Brett/Lynai	2.000	0	9	51	Sat	9:09 pm	to	Sun	7:00 am

Each person is responsible for physically taking their water at the designated day and time. A request to change rotation schedule MUST BE SIGNED BY EACH PERSON on the schedule.

Rotation Id: 10500



Appendix 2
On-Farm Water Conservation Report
(excerpt)

Central Oregon Irrigation District

On-Farm Water Conservation Report

Prepared by:

Black Rock Consulting

320 SW Upper Terrace Drive, Suite #102, Bend, Oregon 97702
(541) 480-6257

&

Farmers Conservation Alliance

11 Third Street, Suite #101, Hood River, Oregon 97031
(541) 716-6085

that these water use requirements are largely based on current crops and may change significantly over time as different crops are grown in the District. Additionally, water use estimates are based on best management practices, assuming that crops are irrigated to meet NIRs, whereas it is likely that other inefficiencies exist in the system such as run-off. For this reason, it is estimated that the current net irrigation requirement may range up to 175,000 acre-feet and the certificated rights are 232,500 acre-feet thus allowing for future crop flexibility, climate change, and other changes over time.

2.4 Operating Costs

For farmers with current pressurized irrigation system practices in place, operating costs include pond liner maintenance, pump maintenance and replacement, filter cleaning and maintenance, irrigation system maintenance and/or replacement, and payment of electricity necessary to operate the pumping system. It is estimated that such annual operational and maintenance costs total approximately $10,000 per irrigated acre per year.

Section 3 Modernized System

To determine the future benefits from a modernized system, the modernization strategies and corresponding water conservation opportunities were evaluated for the privately operated laterals, the on-farm irrigation systems, and a fully modernized system.

3.1 Privately Operated Laterals

The modernization of privately operated laterals would involve piping all of the currently open-channel privately operated laterals in the system. Fully piped privately operated laterals would eliminate seepage, evaporation, and system end-spills associated with privately operated laterals throughout the estimated 250 miles of open laterals. Additional benefits of piped privately operated laterals include reduced ditch maintenance by the patrons, elimination of burning or herbicide applications, elimination of debris and dead animal removal, increased farmable land, and having the infrastructure in place to provide pressurized water to patrons without individual pumps. Without piped privately operated laterals, even if the District's canals were piped and pressurized, that pressurized water would not reach the on-farm application sites. Piping the privately operated laterals would be a step towards getting pressurized water to farms and eliminating the need for holding ponds, water pumps, and the associated energy costs of pumping.

3.1.1 Water Conservation

Privately operated lateral water conservation opportunities were calculated by determining the expected flow rate of each privately operated lateral based on the acreage served and an expected water delivery rate of 6 GPM per acre. The assumed flow rates at 6 GPM per acre for the irrigated acres of a privately operated lateral were then subtracted from the measured flow rates of the same lateral to determine the excess amount of water being delivered via privately operated laterals and thus, the amount of water that could be conserved from a piped privately operated lateral system.

As indicated above and based on a District flow of 6 GPM per acre, expected flow rates from the acreage associated with privately operated laterals (22,712 acres) were 136,272 GPM. However, the measured flow rates were extrapolated to be 188,254 GPM. The difference between the measured and expected flow rates was 51,982 GPM or 114.4 CFS (estimated 35,284 acre-feet). This amount of water represents the estimated water that could be conserved from piping the privately operated laterals.

3.1.2 Costs

Since the privately operated laterals are private systems that are maintained by District patrons and beyond District control, rough estimates were developed for the purposes of estimating the cost of piping these privately operated laterals. It was estimated that roughly 250 miles of privately operated lateral exist in the District and that there are approximately 300 privately operated laterals. These laterals serve approximately 22,712 acres. This results in approximately 4,400 linear feet per lateral at a flow rate of 530 GPM (1.18 CFS) per lateral. Assuming a flow rate of approximately 2 feet per second for privately operated laterals, 12-inch diameter pipe would be needed. Given $16 per linear foot for 12-inch pipe (15% Engineering, 18% CMGC, and 30% Contingency), the total cost was estimated at $36,516,480 for piping all of the privately operated laterals. Given 22,712 acres, this equates to approximately $1,608 per acre to implement. Based upon the estimated savings of 35,284 acre-feet (114.4 CFS) of water per season, this equates to approximately $1,034.93 per acre-foot of water conserved.

3.1.3 Challenges

The main challenges to upgrading the entire privately operated lateral system are costs, a lack of current COID system pressure, challenges with outside funding programs, patron agreement, and easements/legal issues. Assuming an average parcel size in the District of about 11 acres, on average, the total cost to pipe a privately operated lateral was estimated to be $17,688 plus the cost of the turnout to each patron that was roughly estimated to be another $8,000 for a total of $25,688. While this cost could potentially be borne by some larger farming operations, the cost is a significant burden for many irrigators. Additionally, patrons have little reason to pursue piping themselves because there is little incentive for the patrons to pipe. The benefits of the conserved water due to piped privately operated laterals do not directly benefit the patron. If the District's canals and laterals were piped beforehand, however, the patrons may be incentivized to pipe the privately operated laterals because pressurized water could then be delivered to on-farm sites. Patrons could remove the holding ponds and water pumps and eliminate costs associated with pumping. Therefore, the incentive to pipe privately operated laterals would generally only be applicable if the District were already piped.

Another challenge associated with piping the privately operated laterals is landowner agreement. Generally speaking, in order to pipe a privately operated lateral, all the landowners using the lateral must be in agreement to pipe. Because these projects generally require unanimous approval, it can be very difficult to get agreement, depending on the number of users on a privately operated lateral. Additionally, the patrons' ability to work cooperatively is a major factor, as well as the cost burden that all patrons must be willing to bear at the same time. Often these types of piping projects are prevented from moving forward because a single person is unwilling to support the project for any of these aforementioned reasons. Even in situations where a district has incentivized piping the privately operated lateral because the district is delivering pressurized water, patrons that use flood irrigation may not consider piping as a direct benefit to them. Therefore, those patrons may be unwilling to participate in piping a privately operated lateral.

There can also be easement requirements that present hurdles associated with piping privately operated laterals. Although the privately operated lateral may have been acceptable as an open canal to the served patrons, once private piping is implemented, an element of value has been paid for and installed in place of the open ditch. When this occurs, typically an easement is required to provide access to all of the patrons for operation, maintenance, and replacement of the proposed private pipe. Obtaining an easement or easements in favor of a number of private parties is an additional complexity that must be considered in conjunction with the piping of privately operated laterals.

3.2 On-Farm Upgrades

Modernizing irrigation application systems represents a significant opportunity for water conservation. Newer irrigation technologies provide better and more uniform application of water and have greater efficiencies. Implementation of such efficiency upgrades results in less water needed to provide the same amount of water to the crops. Often these more efficient systems improve crop yield and can facilitate the growth of more valuable crops. Additionally, the conveyance system's efficiency is improved along with the application system, since pressurized water and therefore piping is required for modern application systems.

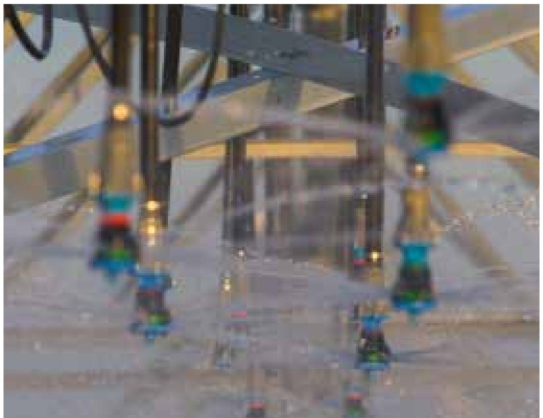
3.2.1 Water Conservation

The amount of water that could be conserved through on-farm irrigation upgrades was determined based on the assumption that all application methods throughout the entire District were upgraded to the most efficient and practical application system possible. Upgraded application systems were assigned an efficiency value based on that of "used" equipment to provide conservative estimates of water use. "Used" equipment efficiency values were preferred over "new" equipment efficiency values because irrigators commonly purchase previously owned equipment. Furthermore, new equipment would experience wear and tear over time, thus

Appendix 3
Product literature for Nelson Irrigation center pivot products

PIVOT POINT TO END GUN

SOLUTIONS FOR MECHANIZED IRRIGATION

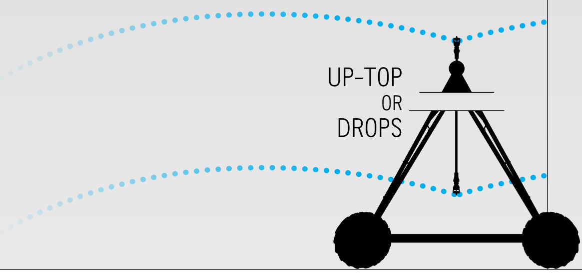


NELSON IRRIGATION CORPORATION OFFERS A FULL RANGE OF WATER APPLICATION SOLUTIONS FOR MECHANIZED IRRIGATION. FROM CONTROL VALVES TO PIVOT SPRINKLERS, AND PRESSURE REGULATORS TO END GUNS — THE PACKAGE IS COMPLETE.

R

ROTATOR®

10-50 psi (0.7-3.4 bar)
50-74' (15.2-22.6 m)



GREATER THROW RADIUS. As a rotating type sprinkler the R3000 & R3030 Rotator® produce a wider pattern resulting in a lower application rate, reduced runoff and longer soak time.

HIGHER UNIFORMITY. The Rotator greatly improves uniformity because of the increased overlap from adjacent sprinklers.

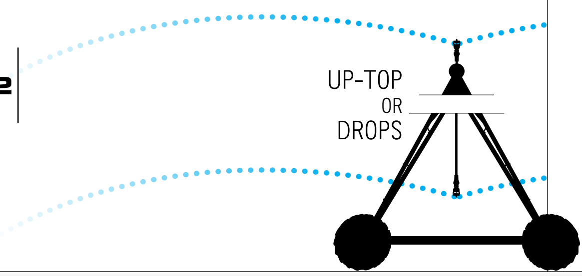
REDUCED WIND DRIFT AND EVAPORATIVE LOSS. The Rotator more than meets the challenge of putting a rotating type sprinkler on drop tubes — down out of the wind — to minimize wind drift and evaporative loss.

NOZZLE: **3TN OR 3NV**
APPLICATION RATE: **LOW**

A

ACCELERATOR

6-15 psi (0.4-1 bar)
30-55' (9.1-16.8 m)



DESIGNED FOR IN-CANOPY WATER APPLICATION. A hybrid sprinkler using both Rotator® and Spinner technology, the Accelerator increases rotation speed as the nozzle size increases. This maximizes throw distance and minimizes evaporative losses at low flow rates. At the end of the system it transforms into a Spinner to lower application rates while treating the soil correctly.

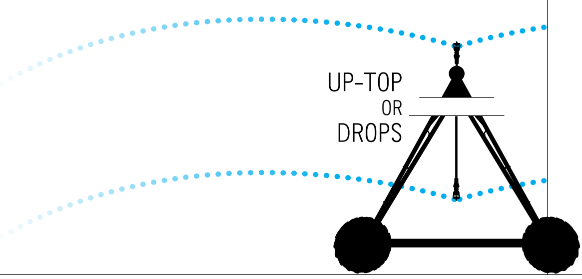
MAXIMUM APPLICATION EFFICIENCY. Operating at 10 psi (0.7 BAR) the A3000 & A3030 maintain the lowest possible trajectory angle without sacrificing throw distance.

NOZZLE: **3TN OR 3NV**
APPLICATION RATE: **LOW-MEDIUM**

S

SPINNER

10-20 psi (0.7-1.4 bar)
42-54' (12.8-16.5 m)

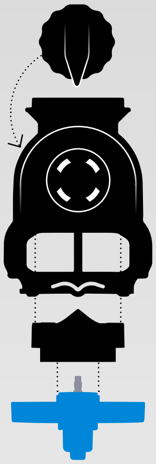


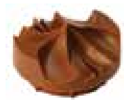
GENTLE RAIN AT LOW PRESSURE. The free-spinning action of the S3000 & S3030 Spinner provides a gentle, rain-like droplet for sensitive soils and crops.

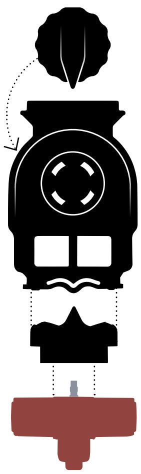
SUPERIOR UNIFORMITY AT LOW PRESSURE. A low pressure alternative to fixed spray-heads, the Spinner provides higher uniformity with better overlap and lower application rates.

NO MOUNTING RESTRICTIONS. The Spinner operates without vibration. Retrofit on rigid, semi-rigid, or flexible drop hose assemblies.

NOZZLE: **3TN OR 3NV**
APPLICATION RATE: **LOW-MEDIUM**



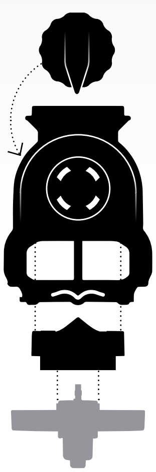
BLUE ROTATOR® CAP	BLUE UP-TOP U4-8°	WHITE UP-TOP	GREEN D4-8°	RED D6-12°	ORANGE MULTI-TRAJECTORY	BROWN MULTI-TRAJECTORY	OLIVE LOW PRESSURE
Nozzles	MAX. #50 NOZ. MIN. #14 NOZ. @ 30 PSI (2.0 BAR) #16 FOR LOW PRESS.	MAX. #50 NOZ. MIN. #14 NOZ. @ 15 PSI (1.0 BAR)	MAX. #50 NOZ. MIN. #14 NOZ. @ 30 PSI (2.0 BAR) #16 FOR LOW PRESS.	MAX. #50 NOZ. MIN. #14 NOZ. @ 15 PSI (1.0 BAR)	MAX. #50 NOZ. MIN. #14 NOZ. @ 15 PSI (1.0 BAR)	MAX. #50 NOZ. MIN. #14 NOZ. @ 15 PSI (1.0 BAR)	MAX. #50 NOZ. MIN. #12 NOZ. @ 10 PSI (0.7 BAR)
Plate							
Performance	70' DIAMETER (21.3 M) AT 12' (3.7 M) MOUNTING @ 30 PSI (2.0 BAR) #32 NOZZLE	74' DIAMETER (22.6 M) AT 12' (3.7 M) MOUNTING @ 30 PSI (2.0 BAR) #32 NOZZLE	72' DIAMETER (21.9 M) AT 9' (2.7 M) MOUNTING @ 30 PSI (2.0 BAR) #32 NOZZLE	66' DIAMETER (20.1 M) AT 9' (2.7 M) MOUNTING @ 25 PSI (1.7 BAR) #36 NOZZLE	72' DIAMETER (21.9 M) AT 9' (2.7 M) MOUNTING @ 25 PSI (1.7 BAR) #36 NOZZLE	68' DIAMETER (20.7 M) AT 9' (2.7 M) MOUNTING @ 25 PSI (1.7 BAR) #36 NOZZLE	58' DIAMETER (17.7) AT 6' (1.8 M) MOUNTING @ 15 PSI (1.0 BAR) #36 NOZZLE
Pressure	20-50 PSI (1.4-3.4 BAR)	15-30 PSI (1.0-2.0 BAR)	20-50 PSI (1.4-3.4 BAR)	15-30 PSI (1.0-2.0 BAR)	15-30 PSI (1.0-2.0 BAR)	15-30 PSI (1.0-2.0 BAR)	10-15 PSI (0.7-1.0 BAR)



MAROON ACCELERATOR CAP	MAROON	GOLD	NAVY UP-TOP
Nozzles	MAX. #50 NOZ. MIN. #10 NOZ. @ 10 PSI (0.7 BAR) #18 @ 6 PSI	MAX. #50 NOZ. MIN. #10 NOZ. @ 15 PSI (1.0 BAR) #12 @10 PSI #18 @ 6 PSI	MAX. #50 NOZ. MIN. #10 NOZ. @ 15 PSI (1.0 BAR) #12 @10 PSI #18 @ 6 PSI
Plate			
Performance	48' DIAMETER (14.6 M) AT 9' (2.7 M) MOUNTING @ 10 PSI (0.7 BAR) #32 NOZZLE	54' DIAMETER (16.5 M) AT 9' (2.7 M) MOUNTING @ 10 PSI (0.7 BAR) #36 NOZZLE	55' DIAMETER (16.8 M) AT 12' (3.7 M) MOUNTING @ 10 PSI (0.7 BAR) #36 NOZZLE
Pressure	6-15 PSI (0.4-1.0 BAR)	6-15 PSI (0.4-1.0 BAR)	6-15 PSI (0.4-1.0 BAR)

OPTIONAL SPRINKLER CONVERTER

EASILY CONVERT FROM ACCELERATOR TO SPRAYHEAD TO BUBBLER



GRAY SPINNER CAP	RED D6-12°	PURPLE D6-20°	YELLOW D8-21°	BEIGE* SMALL NOZZLE	LIME UP-TOP
Nozzles	MAX. #50 NOZ. MIN. #14 NOZ. @ 15 PSI (1.0 BAR) #18 FOR LOW PRESS.	MAX. #50 NOZ. MIN. #14 NOZ. @ 15 PSI (1.0 BAR) #16 FOR LOW PRESS.	MAX. #50 NOZ. MIN. #14 NOZ. @ 15 PSI (1.0 BAR) #16 FOR LOW PRESS.	MAX. #15 NOZ. MIN. #10 NOZ. @ 10 PSI (0.7 BAR)	MAX. #50 NOZ. MIN. #14 NOZ. @ 15 PSI (1.0 BAR)
Plate					
Performance	44' DIAMETER (13.4 M) AT 6' (1.8 M) MOUNTING @ 15 PSI (1.0 BAR) #36 NOZZLE	54' DIAMETER (16.5 M) AT 6' (1.8 M) MOUNTING @ 15 PSI (1.0 BAR) #36 NOZZLE	50' DIAMETER (15.2 M) AT 6' (1.8 M) MOUNTING @ 15 PSI (1.0 BAR) #36 NOZZLE	38' DIAMETER (11.6 M) AT 6' (1.8 M) MOUNTING @ 15 PSI (1.0 BAR) #12 NOZZLE	54' DIAMETER (18.5 M) AT 12' (3.7 M) MOUNTING @ 15 PSI (1.0 BAR) #36 NOZZLE
Pressure	10-20 PSI (0.7-1.4 BAR)	10-20 PSI (0.7-1.4 BAR)	10-20 PSI (.7-1.4 BAR)	10-15 PSI (0.7-1.0 BAR)	6-15 PSI (0.4-1.0 BAR)

PART CIRCLE SPINNER

#14-40 NOZ.
10-20 PSI
(.7-1.4 BAR)

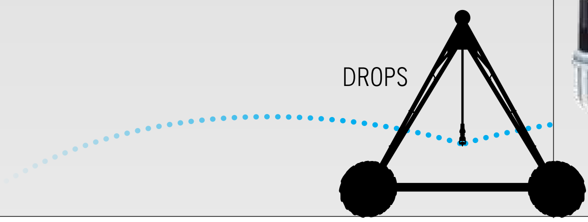
*The beige plate should be used on flexible drops, or those with at least 1ft. (.3 m) of hose. The smaller nozzles will be more susceptible to plugging.

Tel: +1 509.525.7660 / Fax: +1 509.525.7907 / nelsonirrigation.com / info@nelsonirrigation.com

O

ORBITOR

6-20 psi (0.4-1.4 bar)
36-60' (11.0-18.3 m)



STREAMLINED DESIGN. Featuring technology that eliminates the struts of a sprinkler body, Nelson's new Pivot Orbitor provides outstanding uniformity and optimal droplets at low pressures (6-20 psi / 0.4-1.4 bar). Expect long wear life and durability in poor water conditions, because there are no sprinkler body struts for debris to hang up on.

REDUCED WIND DRIFT AND EVAPORATIVE LOSS. Strutless sprinkler body design reduces droplet breakup, drift and drool.

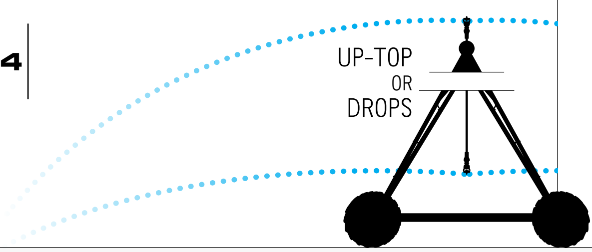
IMPORTANT! THE ORBITOR REQUIRES A MINIMUM OF 2' (0.6 M) OF REINFORCED FLEXIBLE HOSE IN THE MOUNTING ASSEMBLY.

NOZZLE: **3TN OR 3NV**
APPLICATION RATE: **LOW-MEDIUM**

D

SPRAYHEAD

6-40 psi (0.4-2.8 bar)
16-40' (4.9-12.2 m)



GERMINATE, IRRIGATE & CHEMIGATE. The flip-over dual spray cap allows easy conversion of the spray pattern. Choose from spray plate options to germinate, irrigate, and chemigate.

"LOW ENERGY DOWN IN THE CROP". The sleek, crop-guarded body design provides durability for dragging the Sprayhead down in tall growing crops like corn.

OPTIONAL LEPA ACCESSORIES. The hose drag adapter allows simple conversion of the Sprayhead to a hose drag system. Both the D3000 and D3030 have "bubble" modes for LEPA. D3000 requires bubble clip - see page 15.

NOZZLE: **3TN OR 3NV**
APPLICATION RATE: **HIGH**

T

TRASHBUSTER

PRESSURE & THROW DEPENDS ON SPRINKLER SELECTION

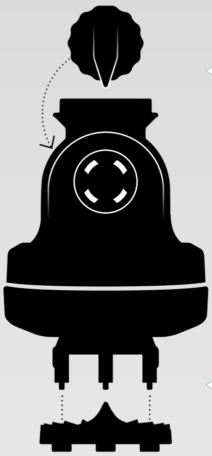
FLOW CONTROL NOZZLE. The Flow Control Nozzle (only available for 3000 Series) not only eliminates the need for pressure regulators, but also passes debris more easily. It is not to be used on flexible hose drop assemblies.

BODY DESIGNED FOR WASTEWATER. The open architecture design of the body allows for debris to pass through more easily, alleviating build up of material on the plate and body.

BY OPERATING ON DROP TUBES you can distribute effluent more days of the year, keep corrosive water off the pivot structure, eliminate excess wind/pathogen drift, and reduce odor. The Trashbuster can be configured into either a Spray or Rotator sprinkler.

NOZZLE: **3TN OR 3000FC**
APPLICATION RATE: **LOW-HIGH**

THROW DIAMETER, PRESSURE & NOZZLE RANGE



#11-#50 NOZ. NOZZLE RANGE	#11-#50 NOZ. NOZZLE RANGE	#11-#50 NOZ. NOZZLE RANGE
BLACK STANDARD ANGLE	**BLUE LOW ANGLE**	**PURPLE SMALL DROPLET**
		
58' DIAMETER (17.7 M) AT 6' (1.8 M) MOUNTING @ 15 PSI (1.0 BAR) #36 NOZZLE	50' DIAMETER (15.2 M) AT 6' (1.8 M) MOUNTING @ 15 PSI (1.0 BAR) #36 NOZZLE	47' DIAMETER (14.3 M) AT 6' (1.8 M) MOUNTING @ 15 PSI (1.0 BAR) #36 NOZZLE
6-20 PSI (0.4-1.4 BAR)	6-20 PSI (0.4-1.4 BAR)	6-20 PSI (0.4-1.4 BAR)

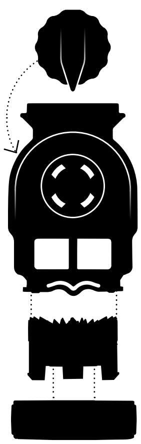
ORBITOR WITH WEIGHTED COVER

ORBITOR WITH PLASTIC COVER

IMPORTANT MOUNTING INFORMATION:

1. The Orbitor requires a minimum of 2' (0.6 m) of reinforced flexible hose in the mounting assembly.
2. When using the Orbitor with the weighted cover, do not use any other conventional weight styles instead of, or in addition to, the Orbitor weight.
3. When using the Orbitor with the plastic cover, an inline weight is required. Use Nelson Slim Weights (page 25) or 3/4" NPT threaded weights. Slip weights require the Nelson Clamp Saver (page 25).
4. Always be sure that the Orbitor Weight, Slim Weight, or threaded weight is securely tightened.
5. Always be sure that all components in the mounting assembly and the Orbitor are securely tightened. Use new* Nelson pressure regulators and fittings.
6. If ¾" ball valves are used, use metal nipples or Nelson P/N-12291 plastic nipples.

*New, patented single-strut seat manufactured after 2007.



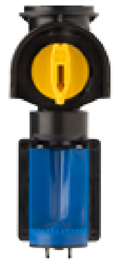
BLACK FLIP-OVER SPRAYHEAD CAP

TURQUOISE 	GREEN 	BLUE 	GRAY 
RED 	YELLOW 	BLACK 	ORANGE 
WHITE 	PURPLE 	BROWN 	

SEE SPRAYHEAD LITERATURE FOR PLATE CHARACTERISTICS, THROW DIAMETER AND PRESSURE/NOZZLE RANGES. THE SPRAYHEAD CAN BE USED UP-TOP OR ON DROPS.

ACCESSORIES

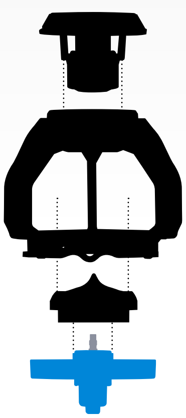
3030 SERIES PART-CIRCLE SPRAY & HOSE DRAG ADAPTER BOTH REQUIRE UNIVERSAL BODY - 3000 SERIES DOES NOT



PART CIRCLE SPRAY #9894-001

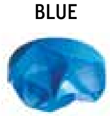
HOSE DRAG ADAPTER #9427

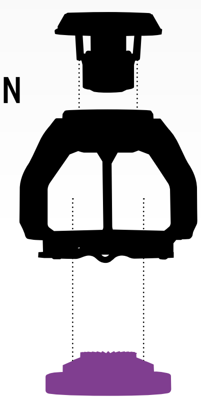
BUBBLER ATTACHMENT (LEPA) #10577 FOR D3000 ONLY



BLUE ROTATOR CAP

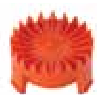
ROTATOR® CONFIGURATION

BLUE 
GREEN 



PURPLE T3000 CAP & SPRAY PLATE

SPRAYHEAD CONFIGURATION

GREEN 	YELLOW 	PURPLE 
BLUE 	BLACK 	ORANGE 

3000FC NOZZLE #10106-XXX REQUIRES A RIGID DROP AND 25 PSI (1.7 BAR) MINIMUM.

Appendix 4
Product literature for the Wade Rain Poweroll products

13. How much pressure do I need?

Depending on the line length and irrigated area, Poweroll systems usually require between 30 and 50 PSI for operation.

14. Is it expensive?

When measured on a per hectare basis, which is the only accurate way to compare irrigation systems, Poweroll is the least expensive mechanical irrigation system on the market today. For one 30 hectare system the average cost is about $500 per hectare, not including freight, duties, etc. This compares very favorably with other mechanical irrigation systems or cost of land levelling.

Appendix 5
Product literature for the K-Line irrigation system

K-Line Sprinkler Options

There are five reliable sprinkler packages currently offered for the K-Line system. The first is the NAAN 5022 Impact sprinkler this sprinkler has a solid one piece body constructed of heavy duty plastics that provide resistance to impact and corrosion. This sprinkler has the option of 5 quick-release color coded nozzles with a variety of application rates to fit varying needs. With operating pressures in the range of 35-55 psi and high uniformities this sprinkler is a perfect fit for the K-Line system.

The second, third, and fourth options utilize the Nelson R2000WF WindFighter and Nelson R33 sprinklers. The Windfighter has a wide variety of nozzles and plates so that the application rates can be tailored to individual needs. Another excellent feature of the Windfighter is the option of a pressure regulator. This option greatly improves uniformity when K-line is used on hilly or undulating ground. The Nelson Windfighter has an operating range between 45-60 psi and provides another excellent choice for use in the K-line system. The Nelson R33 offers the same superb performance in a 3/4" option.

The fourth (below) is the Rain Bird LF (low flow) 2400 impact sprinkler. This Rain Bird sprinkler is one of the most robust sprinklers in it's class which translates to less breakage, less maintenance, and less out of pocket expense. This sprinkler currently has the option of 3 color coded nozzles ranging from 2.35 gpm at 35 psi to 4.02 gpm at 45 psi.

All four sprinkler options install quickly into the K-line system using either a 32, 40, or 45mm tapping saddle. After drilling the tubing in the desired location simply insert the tapping saddle over the u-bolt in the bottom of the pod, line up the saddle with the hole in the tubing, push down firmly to seat the o-ring, and tighten the two stainless steel nuts.

Appendix 6
Oregon Crop Water Use and Irrigation Requirements (excerpt)

EXCERPT

Extension Miscellaneous 8530

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$12.00

Oregon Crop Water Use and Irrigation Requirements

Water Resources Engineering Team, Department of Bioresource Engineering, Agricultural Experiment Station, and OSU Extension Service, Oregon State University; Diputación General de Aragón, Servicio de Investigación Agraria, Zaragoza, España (Spain); U.S. Department of Agriculture, Office of International Cooperation and Development; and Water Resources Department, State of Oregon

Oregon State University Extension Service

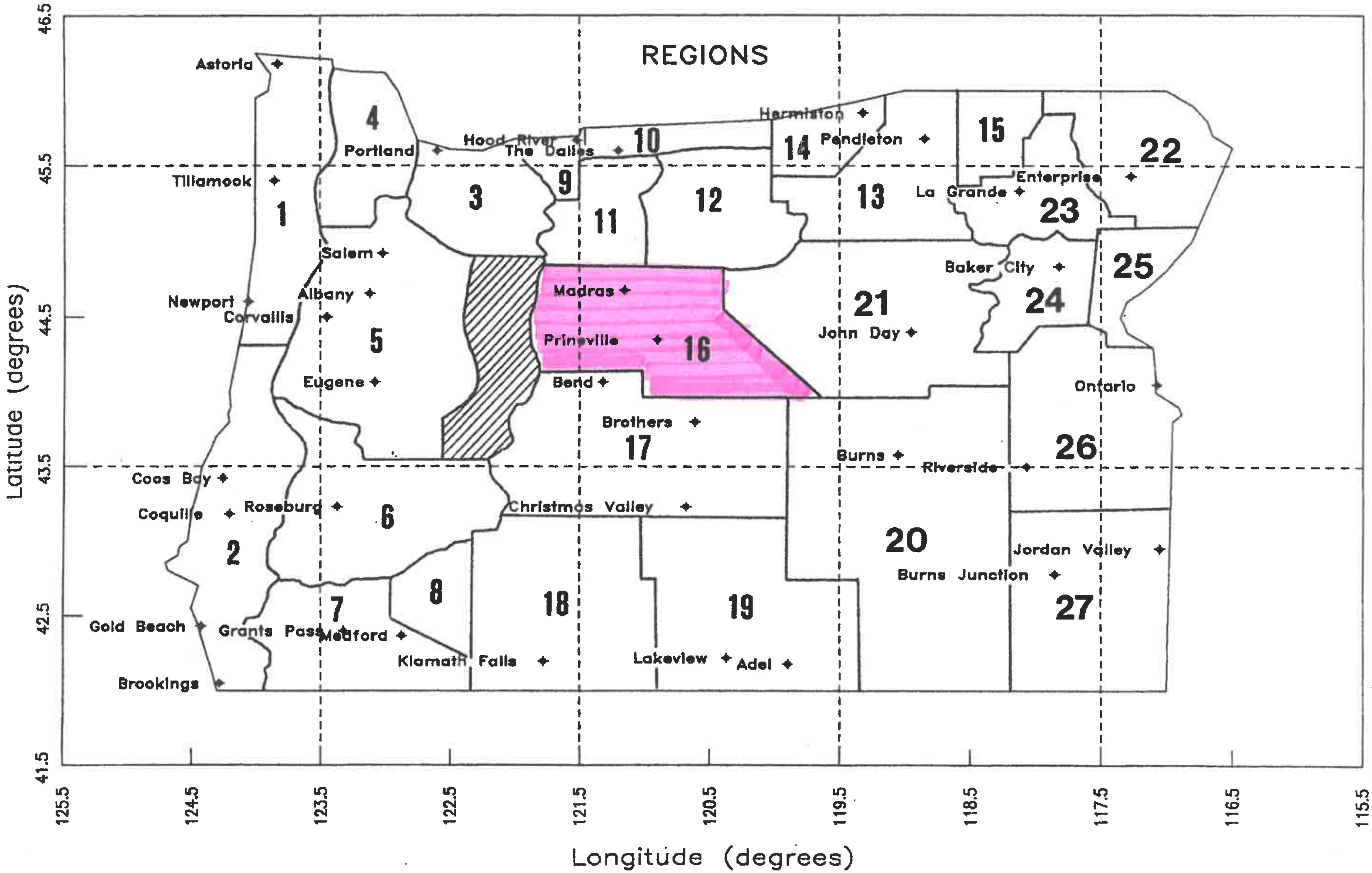
REGIONS
Astoria
Portland
Hood River
The Dalles
Hermiston
Pendleton
Tillamook
Enterprise
La Grande
Salem
Baker City
Newport
Albany
Corvallis
John Day
Eugene
Madras
Prineville
Bend
Ontario
Brothers
Burns
Riverside
Coos Bay
Coquille
Roseburg
Christmas Valley
Jordan Valley
Burns Junction
Gold Beach
Grants Pass
Medford
Klamath Falls
Lakeview
Adel
Brookings
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
Latitude (degrees)
46.5
45.5
44.5
43.5
42.5
41.5
Longitude (degrees)
125.5
124.5
123.5
122.5
121.5
120.5
119.5
118.5
117.5
116.5
115.5

Table 1. Typical growing season of selected Oregon crops by region.

Region	Alfalfa Hay	Beans	Berries	Corn Field	Corn Silage	Corn Sweet	Fruit Trees
Coastal							
1 North					May 05–Sep 15		*
2 South					May 20–Oct 01		*
Willamette Valley							
3 Columbia River below Hood R.	Apr 10–Nov 08	May 01–Jul 25	Apr 30–Nov 23	May 05–Sep 20	May 05–Sep 08	May 12–Sep 10	*
4 Tualatin	Apr 10–Nov 08	May 01–Jul 25	Apr 30–Nov 23	May 05–Sep 20	May 05–Sep 08	May 12–Sep 10	*
5 Willamette	Apr 10–Nov 08	May 01–Jul 25	Apr 30–Nov 23	May 05–Sep 20	May 05–Sep 08	May 12–Sep 10	*
Southwestern Valleys							
6 Umpqua River	Mar 15–Oct 01	May 01–Jul 25			May 05–Sep 08	May 01–Sep 15	*
7 Medford–Grants Pass	Mar 29–Oct 01				May 05–Sep 08		*
8 Lake Creek–Little Butte Creek	Mar 29–Oct 01				May 05–Sep 08	May 01–Sep 15	*
North Central							
9 Hood River Valley	Apr 10–Oct 01		May 21–Oct 24	May 05–Oct 01		May 15–Sep 05	*
10 Columbia River above Hood R.	Apr 10–Oct 01		May 14–Nov 07				*
11 East Slope of Mt. Hood	Apr 10–Oct 01		May 21–Oct 24				*
12 Columbia Basin Wheat Land	Apr 10–Oct 01		May 14–Nov 07				*
13 Pendleton–Heppner	Apr 10–Oct 01		May 14–Nov 07	May 05–Oct 01		May 15–Aug 20	*
14 Hermiston	Apr 10–Oct 01		May 14–Nov 07	May 05–Oct 01		May 15–Aug 20	*
15 Milton–Freewater	Mar 10–Oct 01		May 14–Nov 07			May 15–Aug 20	*
South Central							
16 Madras–Redmond	Apr 10–Oct 01				May 05–Oct 01		
17 Bend	Apr 10–Oct 01					May 15–Sep 05	
18 Klamath	May 15–Aug 30						
19 Lakeview	May 15–Aug 30						
20 Harney Valley	May 15–Aug 30						
21 Dayville–Canyon City	Apr 10–Oct 01						
Northeast							
22 Wallowa Valley	Apr 10–Oct 01						
23 Grande Ronde Valley	Apr 10–Oct 01						
24 Baker Valley	Apr 10–Oct 01			May 05–Oct 01		May 15–Sep 05	
25 Pine and Eagle Valleys	Apr 10–Oct 01			May 05–Oct 01		May 15–Sep 05	
Southeast							
26 Malheur	Apr 03–Jul 23			May 03–Oct 15	May 03–Oct 01	May 03–Aug 14	
27 Jordan Valley	Apr 03–Jul 23			May 03–Oct 15	May 03–Oct 01		

Table 1. Typical growing season of selected Oregon crops by region. (continued)

Region	Grain Spring	Grain Winter	Grass Seed Spring	Grass Seed Fall	Mint	Onions	Pasture
Coastal							
1 North							Mar 20–Oct 30
2 South							Mar 20–Oct 30
Willamette Valley							
3 Columbia River below Hood R.	Mar 15–Aug 10	Mar 05–Aug 05	Apr 01 – Mar 31	Oct 01–Sep 30		Apr 15–Sep 01	Mar 10–Nov 15
4 Tualatin	Mar 15–Aug 10	Mar 05–Aug 05	Apr 01 – Mar 31	Oct 01–Sep 30		Apr 15–Sep 01	Mar 10–Nov 15
5 Willamette	Mar 15–Aug 10	Mar 05–Aug 05	Apr 01 – Mar 31	Oct 01–Sep 30	Mar 15–Jul 28	Apr 15–Sep 01	Mar 10–Nov 15
Southwestern Valleys							
6 Umpqua River	Mar 15–Aug 08	Mar 05–Aug 01	Apr 01–Mar 31				Mar 01–Nov 15
7 Medford–Grants Pass	Mar 15–Aug 08	Mar 05–Aug 01	Apr 01–Mar 31			Mar 15–Sep 01	Mar 01–Nov 15
8 Lake Creek–Little Butte Creek	Mar 15–Aug 08	Mar 05–Aug 01	Apr 01–Mar 31			Mar 15–Sep 01	Mar 01–Nov 15
North Central							
9 Hood River Valley	Apr 01–Aug 16	Mar 05–Jul 20				Apr 20–Sep 15	Mar 20–Oct 30
10 Columbia River above Hood R.	Apr 01–Aug 16	Mar 05–Jul 20	Apr 01–Mar 31				Mar 20–Oct 30
11 East Slope of Mt. Hood	Apr 01–Aug 16	Mar 05–Jul 20	Apr 01–Mar 31				Mar 20–Oct 30
12 Columbia Basin Wheat Land	Apr 01–Aug 16	Mar 05–Jul 20	Apr 01–Mar 31				Mar 20–Oct 30
13 Pendleton–Heppner	Apr 01–Aug 16	Mar 05–Aug 01				Mar 25–Sep 22	Mar 20–Oct 30
14 Hermiston	Mar 15–Aug 16	Mar 05–Aug 01			Mar 30–Aug 07	Mar 25–Sep 22	Mar 20–Oct 30
15 Milton–Freewater	Mar 15–Aug 28	Mar 05–Aug 01				Mar 25–Sep 22	Mar 20–Oct 30
South Central							
16 Madras–Redmond	Apr 01–Aug 16	Mar 15–Aug 10	Apr 01–Mar 31	Oct 01–Sep 30	Mar 30–Aug 07	Apr 20–Sep 15	Apr 12–Oct 24
17 Bend	Apr 01–Aug 16	Mar 15–Aug 10			Mar 30–Aug 07		Apr 12–Oct 24
18 Klamath	May 10–Sep 15	Apr 05–Aug 10					Apr 01–Oct 15
19 Lakeview	May 10–Sep 15	Apr 05–Aug 10					Apr 01–Oct 15
20 Harney Valley	May 10–Sep 15	Apr 05–Aug 10			Mar 30–Aug 07		Apr 01–Oct 15
21 Dayville–Canyon City	Apr 01–Aug 16	Mar 15–Aug 01			Mar 30–Aug 07		Apr 12–Oct 24
Northeast							
22 Wallowa Valley	Apr 01–Aug 16	Mar 15–Aug 01	Apr 01–Mar 31				Mar 20–Oct 30
23 Grande Ronde Valley	Apr 01–Aug 16	Mar 15–Aug 01	Apr 01–Mar 31	Oct 01–Sep 30	Mar 30–Aug 07		Mar 20–Oct 30
24 Baker Valley	Apr 01–Aug 16	Mar 15–Aug 01	Apr 01–Mar 31			Apr 20–Sep 15	Mar 20–Oct 30
25 Pine and Eagle Valleys	Apr 01–Aug 16	Mar 15–Aug 01	Apr 01–Mar 31			Apr 20–Sep 15	Mar 20–Oct 30
Southeast							
26 Malheur	Mar 28–Aug 08	Feb 09–Aug 01	Apr 01–Mar 31			Apr 04–Aug 28	Mar 27–Oct 31
27 Jordan Valley	Mar 28–Aug 08	Feb 09–Aug 01	Apr 01–Mar 31			Apr 04–Aug 28	Mar 27–Oct 31

REGION: 16 Madras-Redmond
CROP: Alfalfa Hay

MONTH	5 out of 10 years		6 out of 10 years		7 out of 10 years		8 out of 10 years		9 out of 10 years		19 out of 20 years	
	ET crop mm in.	Net IRR mm in.	ET crop mm in.	Net IRR mm in.	ET crop mm in.	Net IRR mm in.	ET crop mm in.	Net IRR mm in.	ET crop mm in.	Net IRR mm in.	ET crop mm in.	Net IRR mm in.
April	56 (2.20)	47 (1.85)	57 (2.24)	49 (1.93)	58 (2.28)	50 (1.97)	60 (2.36)	56 (2.20)	63 (2.48)	60 (2.36)	65 (2.56)	62 (2.44)
May	114 (4.49)	91 (3.58)	116 (4.57)	96 (3.78)	117 (4.61)	100 (3.94)	120 (4.72)	104 (4.09)	125 (4.92)	109 (4.29)	130 (5.12)	114 (4.49)
June	136 (5.35)	111 (4.37)	137 (5.39)	117 (4.61)	138 (5.43)	123 (4.84)	140 (5.51)	129 (5.08)	146 (5.75)	137 (5.39)	148 (5.83)	143 (5.63)
July	167 (6.57)	159 (6.26)	168 (6.61)	162 (6.38)	169 (6.65)	165 (6.50)	171 (6.73)	168 (6.61)	173 (6.81)	173 (6.81)	175 (6.89)	175 (6.89)
Aug	131 (5.16)	127 (5.00)	134 (5.28)	129 (5.08)	137 (5.39)	131 (5.16)	140 (5.51)	135 (5.31)	145 (5.71)	142 (5.59)	149 (5.87)	146 (5.75)
Sep	97 (3.82)	84 (3.31)	99 (3.90)	87 (3.43)	101 (3.98)	92 (3.62)	103 (4.06)	97 (3.82)	106 (4.17)	102 (4.02)	108 (4.25)	104 (4.09)
Season	701 (27.59)	619 (24.37)	711 (27.99)	640 (25.21)	720 (28.34)	661 (26.03)	734 (28.89)	689 (27.11)	758 (29.84)	723 (28.46)	775 (30.52)	744 (29.29)

REGION: 16 Madras-Redmond
CROP: Corn (Silage)

MONTH	5 out of 10 years		6 out of 10 years		7 out of 10 years		8 out of 10 years		9 out of 10 years		19 out of 20 years	
	ET crop mm in.	Net IRR mm in.	ET crop mm in.	Net IRR mm in.	ET crop mm in.	Net IRR mm in.	ET crop mm in.	Net IRR mm in.	ET crop mm in.	Net IRR mm in.	ET crop mm in.	Net IRR mm in.
May	57 (2.24)	41 (1.61)	57 (2.24)	45 (1.77)	58 (2.28)	47 (1.85)	59 (2.32)	50 (1.97)	60 (2.36)	52 (2.05)	62 (2.44)	55 (2.17)
June	122 (4.80)	98 (3.86)	124 (4.88)	105 (4.13)	125 (4.92)	112 (4.41)	127 (5.00)	118 (4.65)	132 (5.20)	125 (4.92)	135 (5.31)	131 (5.16)
July	201 (7.91)	192 (7.56)	202 (7.95)	196 (7.72)	204 (8.03)	200 (7.87)	205 (8.07)	204 (8.03)	208 (8.19)	208 (8.19)	211 (8.31)	211 (8.31)
Aug	161 (6.34)	155 (6.10)	164 (6.46)	159 (6.26)	168 (6.61)	162 (6.38)	171 (6.73)	166 (6.54)	178 (7.01)	174 (6.85)	184 (7.24)	179 (7.05)
Sep	113 (4.45)	98 (3.86)	115 (4.53)	103 (4.06)	117 (4.61)	108 (4.25)	120 (4.72)	112 (4.41)	124 (4.88)	119 (4.69)	126 (4.96)	122 (4.80)
Season	654 (25.74)	584 (22.99)	662 (26.06)	608 (23.94)	672 (26.45)	629 (24.76)	682 (26.84)	650 (25.60)	702 (27.64)	678 (26.70)	718 (28.26)	698 (27.49)

REGION: 16 Madras-Redmond
CROP: Pasture

MONTH	5 out of 10 years				6 out of 10 years				7 out of 10 years				8 out of 10 years				9 out of 10 years				19 out of 20 years			
	ET crop mm	in.	Net IRR mm	in.	ET crop mm	in.	Net IRR mm	in.	ET crop mm	in.	Net IRR mm	in.	ET crop mm	in.	Net IRR mm	in.	ET crop mm	in.	Net IRR mm	in.	ET crop mm	in.	Net IRR mm	in.
April	54	(2.13)	46	(1.81)	55	(2.17)	48	(1.89)	57	(2.24)	50	(1.97)	58	(2.28)	53	(2.09)	62	(2.44)	59	(2.32)	64	(2.52)	61	(2.40)
May	120	(4.72)	98	(3.86)	122	(4.80)	103	(4.06)	124	(4.88)	108	(4.25)	128	(5.04)	112	(4.41)	133	(5.24)	117	(4.61)	138	(5.43)	122	(4.80)
June	144	(5.67)	120	(4.72)	146	(5.75)	128	(5.04)	147	(5.79)	133	(5.24)	149	(5.87)	139	(5.47)	156	(6.14)	146	(5.75)	158	(6.22)	152	(5.98)
July	178	(7.01)	169	(6.65)	179	(7.05)	173	(6.81)	180	(7.09)	176	(6.93)	182	(7.17)	179	(7.05)	184	(7.24)	183	(7.20)	187	(7.36)	187	(7.36)
Aug	141	(5.55)	134	(5.28)	142	(5.59)	137	(5.39)	145	(5.71)	140	(5.51)	149	(5.87)	144	(5.67)	155	(6.10)	151	(5.94)	159	(6.26)	156	(6.14)
Sep	103	(4.06)	91	(3.58)	105	(4.13)	94	(3.70)	107	(4.21)	98	(3.86)	110	(4.33)	102	(4.02)	113	(4.45)	109	(4.29)	115	(4.53)	111	(4.37)
Oct	52	(2.05)	39	(1.54)	53	(2.09)	41	(1.61)	54	(2.13)	44	(1.73)	55	(2.17)	46	(1.81)	58	(2.28)	54	(2.13)	59	(2.32)	57	(2.24)
Season	792	(31.19)	697	(27.44)	802	(31.58)	724	(28.50)	814	(32.05)	749	(29.49)	831	(32.73)	775	(30.52)	861	(33.89)	819	(32.24)	880	(34.64)	846	(33.29)

REGION: 16 Madras-Redmond
CROP: Peas

MONTH	5 out of 10 years				6 out of 10 years				7 out of 10 years				8 out of 10 years				9 out of 10 years				19 out of 20 years			
	ET crop mm	in.	Net IRR mm	in.	ET crop mm	in.	Net IRR mm	in.	ET crop mm	in.	Net IRR mm	in.	ET crop mm	in.	Net IRR mm	in.	ET crop mm	in.	Net IRR mm	in.	ET crop mm	in.	Net IRR mm	in.
April	36	(1.42)	29	(1.14)	36	(1.42)	31	(1.22)	37	(1.46)	32	(1.26)	38	(1.50)	35	(1.38)	40	(1.57)	37	(1.46)	41	(1.61)	39	(1.54)
May	123	(4.84)	101	(3.98)	126	(4.96)	105	(4.13)	128	(5.04)	109	(4.29)	130	(5.12)	114	(4.49)	135	(5.31)	119	(4.69)	138	(5.43)	124	(4.88)
June	164	(6.46)	134	(5.28)	166	(6.54)	142	(5.59)	168	(6.61)	152	(5.98)	170	(6.69)	157	(6.18)	178	(7.01)	167	(6.57)	180	(7.09)	173	(6.81)
July	157	(6.18)	152	(5.98)	158	(6.22)	155	(6.10)	159	(6.26)	157	(6.18)	161	(6.34)	160	(6.30)	163	(6.42)	163	(6.42)	165	(6.50)	165	(6.50)
Season	480	(18.90)	416	(16.38)	486	(19.14)	433	(17.04)	492	(19.37)	450	(17.71)	499	(19.65)	466	(18.35)	516	(20.31)	486	(19.14)	524	(20.63)	501	(19.73)

Table 5. Suggested combined application and distribution pattern efficiencies in percent for various types of irrigation systems assuming reasonable system design and management.

SYSTEM	COMBINED EFFICIENCY LOW	COMBINED EFFICIENCY HIGH
Basin, level border, level furrow, graded border, or graded furrow surface with tailwater return	80	95
Graded border and graded furrow surface with no tailwater return but with cutback	65	75
Graded border and graded furrow surface with no tailwater return and no cutback	40	65
Hand-move and side-roll sprinkler with offsets	70	80
Solid set sprinkler with low wind design	55	65
Solid set sprinkler with high wind design	65	75
Big gun with low wind design	60	70
Big gun with high wind design	70	80
Continuous move sprinkler - center pivot or linear move	75	85
Trickle (or drip)	80	90
Subsurface	85	95