
The International Society of Precision Agriculture presents the
16th International Conference on
Precision Agriculture
21–24 July 2024 | Manhattan, Kansas USA

INTEROPERABILITY AS AN ENABLER FOR PRINCIPLED DECISION-MAKING IN IRRIGATION: THE PRECISION AGRICULTURE IRRIGATION LANGUAGE (PAIL)

Craker B.[1], Ferreyra R. A.[2], Fuller D. H.[3], Hillyer C.[4]; Watanabe K[5]

[1]Portfolio Manager - AgGateway, USA; [2]Industry Data Standards and Collaborations Lead, Syngenta, Murray, KY USA*; [3]Spatial Data Analyst, IoT and Agronomic Data Platforms, Syngenta USA; [4]Director, Center for Irrigation Technology, California State University, Fresno, USA; [5]Graduate Research Assistant - Mississippi State University, USA

*** Corresponding author**

A paper from the Proceedings of the
16th International Conference on Precision Agriculture
21-24 July 2024
Manhattan, Kansas, United States

Abstract

Fresh water is a scarce resource, and agriculture consumes a high fraction of it worldwide. As climate change increases the likelihood of high temperatures and droughts, irrigation becomes an increasingly attractive option for managing crop production risks. Unfortunately, and despite decades of efforts by professional associations to promote the use of a principled, data-driven approach to irrigation scheduling often called scientific irrigation scheduling (SIS), the fraction of farmers using SIS remains quite low.

In the early 2010s the Northwestern Energy Efficiency Alliance (NEAA), a USA group funded by electric utility companies, sought to demonstrate the value of SIS as a mechanism for optimizing energy (and water) use in irrigation. Their effort was soon crippled by a lack of data interoperability; it was impossible to bring together at scale the necessary high-quality data inputs (e.g., from weather and soil water sensors) and outputs (e.g., the capability to send work orders to an irrigation system).

This led to a decade-long effort spanning AgGateway (a nonprofit industry consortium for data interoperability), ASABE (the American Soc. For Agricultural and Biological Engineers), ANSI (the American National Standards Institute) and ISO (The International Organization for Standardization). The purpose of this work was to produce a three-part standard to:

Part 1: Define a set of basic data objects common to different agricultural field operations compatible with AgGateway's ADAPT (Agricultural Data Application Programming Toolkit),

---

The authors are solely responsible for the content of this paper, which is not a refereed publication. Citation of this work should state that it is from the Proceedings of the 16th International Conference on Precision Agriculture. EXAMPLE: Last Name, A. B. & Coauthor, C. D. (2024). Title of paper. In Proceedings of the 16th International Conference on Precision Agriculture (unpaginated, online). Monticello, IL: International Society of Precision Agriculture.

Part 2: Create a practical and usable data model for the inputs to irrigation management decisions based on the ISO 19156 standard for Observations and Measurements, and

Part 3: Create a practical and usable data model for communicating planned and actual placement of water and associated products (e.g., for chemigation / fertigation).

Parts 1 and 3 currently exist as ASABE / ANSI US National Standards S632-1 and S632-3. Updated versions of these, along with Part 2, are coursing their way through the ISO standards development under the ISO 7673 name. Reference XML and JSON schemas that implement the data objects are freely available from https://aggateway.atlassian.net/wiki/x/1gATB.

This paper describes the different irrigation use cases and technologies (e.g., center pivot, drip, flood, and solid set systems) supported by the standard. It also describes the ISO 7673-2 implementation of the ISO 19156 observations and measurements abstract model and its link to other aspects of the ISO strategy for supporting interoperability in data-driven agrifood systems. Finally, the paper lays out the changes and enhancements made along the way to meet the needs of international stakeholders and their irrigation systems of interest.

Keywords.
irrigation, water, data, interoperability, standards, field operations, sensor, observation, measurement

Introduction

Fresh water is a scarce resource, and agriculture consumes a high fraction of the world supply. As climate change makes high temperatures and droughts more likely, irrigation becomes a more attractive option for managing crop production risks. For decades, professional associations have been promoting a principled, data-driven approach to irrigation scheduling, often called scientific irrigation scheduling (SIS). Unfortunately, the fraction of farmers using SIS remains quite low.

In the early 2010s the Northwestern Energy Efficiency Alliance (NEAA), a USA group funded by electric utility companies, sought to demonstrate the value of SIS as a mechanism for enabling decision support systems (DSS) to optimize energy (and water) use in irrigation. Their effort was soon crippled by a lack of data interoperability; it was impossible to bring together at scale the necessary high-quality data inputs (e.g., from weather and soil water sensors) and outputs (e.g., the capability to send work orders to an irrigation system).

AgGateway's PAIL project emerged from the NEAA initiative (https://neea.org/resources/agricultural-irrigation-initiative-overview) to work toward resolving the interoperability issues among the manufacturers of irrigation equipment, environmental sensors, farm management information systems (FMIS) and service providers. NEEA identified developing an industry-wide agreement on data standards as the first step needed to overcome the interoperability obstacle; PAIL was created for that purpose.

A 10-year effort ensued, involving AgGateway (a nonprofit industry data interoperability consortium), ASABE (American Soc. for Agricultural and Biological Engineers), ANSI (American National Standards Institute) and ISO (International Organization for Standardization).

The goals of this paper are:

- Describe the different irrigation use cases and technologies (e.g., center pivot, drip, flood, and solid set systems) supported by the standard.
- Describe the ISO 7673-2 implementation of the ISO 19156 observations and measurements model and its link to other aspects of the ISO smart farming strategy.
- Describe the changes and enhancements made along the way to meet the needs of international stakeholders and their irrigation systems of interest.

The ISO 7673 Series of Standards

The PAIL, or ISO 7673 standards, which, as of this writing, are at the draft international standard (DIS) stage, currently exist as a series of three parts:

- Part 1: Core Concepts, Processes, and Objects
- Part 2: Observations and Measurements
- Part 3: Irrigation Operations

Each part is described below.

Core Concepts, Processes, and Objects

The goal of ISO 7673-1 is to define a set of basic data objects common to different agricultural field operations, and compatible with AgGateway's ADAPT (Agricultural Data Application Programming Toolkit). This formalizes the Core Documents, Compound Identifiers, Context Items, and other related objects that came out of AgGateway's SPADE (Standardized Precision Agricultural Data Exchange) project. Business Process Modeling Notation (BPMN) was used to represent use cases to clearly document the actors, business processes, and data exchanges that happen in the context of different field operation scenarios.

The core documents model captures the business processes that take place on a farm whether they be technical exchanges among computer systems, or less formally with few parties involved (e.g., the farm manager). While the documents are flexible enough to support all processes, though perhaps simplified, for the purposes of this work the focus is on enabling the exchange of data among systems.

Following the process a farmer uses through the season is a good way to help understand each document's role and how they interact.

- The first document is the Crop Plan, essentially specifying what crop will be grown where and how for the season.
- Observations and Measurements represent sensor readings, crop scouting reports and other information collected to inform a Recommendation.
- A Recommendation is something often developed by an advisor with more detail on when and how specific products should be applied.
- The farm manager can then review the Recommendation, potentially adjusting it to create a Work Order, a detailed plan on what is intended to happen during a specific operation.
- The Work Record is the result of the Work Order; it represents what was really done in the field, which frequently differs from what was planned.
- Finally, Reference, Setup and Configuration Data are information needed to contextualize (and be referenced by) the other documents (e.g., farms, fields, products, people, etc.).

Documenting the process described above requires definition of several central concepts. These concepts include identity (via the CompoundIdentifier class), time (via the TimeScope class), space (via several classes), units of measure, and documentation of geopolitical context dependent data via the ContextItem class, as well as multiple Reference and Setup data classes. All the above classes are foundational and used throughout the ISO 7673 series; describing them in detail is beyond the scope of this paper (Please refer to the standards); a short list follows:

- **Reference Data** represents information, typically provided by a manufacturer, that is applicable to all instances of a thing (e.g., the series or model number of a kind of machine, or the formulation of a particular branded chemical product). Controlled vocabularies typically fall under this category.
- **Setup Data** represents basic information about a producer, farm, fields, and actors. This may include farm names, field boundaries, etc. Setup data is often also called master data.
- **Configuration Data** specifies the particular state of specific instances of things such as farm equipment and instruments (e.g. soil sensors, irrigation pivots, combines, etc.) This

may include their location, what they are connected to, who installed them, etc.

Observations and Measurements

Principled decision-making in agriculture often requires data collected from sensors in the field and other data sources such as forecast models. One of the main interoperability issues limiting adoption of principled decision-making is that the observations and measurements data that drive the decisions are not easily understood by the various actors and systems used to drive decisions such as irrigation recommendations.

The goal of part 2 is to create a practical and usable data model to represent and exchange the data used as inputs to agricultural field operations management decisions, based on the ISO 19156 standard for Observations and Measurements. The kinds of data involved range from field scouting observations (e.g., of crop phenological stages, disease and pest pressure) to agricultural laboratory test results to data from weather stations and other environmental sensors (e.g., soil water content), to data from assets such as grain dryers and scales.

The ISO 19156 model is shown in simplified form in Figure 1, as a Unified Modeling language (UML) class diagram. The Observation class at the center represents the act of applying one or more Procedures or methods to obtain a Result or value (e.g., “32 degrees Celsius”) for an Observed property (e.g., temperature) of a Feature of interest (e.g., the air in an agricultural field at a certain latitude & longitude). This observation will have some Metadata (e.g., who took it, when the instrument was last calibrated), and a certain context which, in our case, was focused on keeping related observations together, such as all the other measurements of humidity, wind speed, etc. that might have accompanied the temperature measurement.

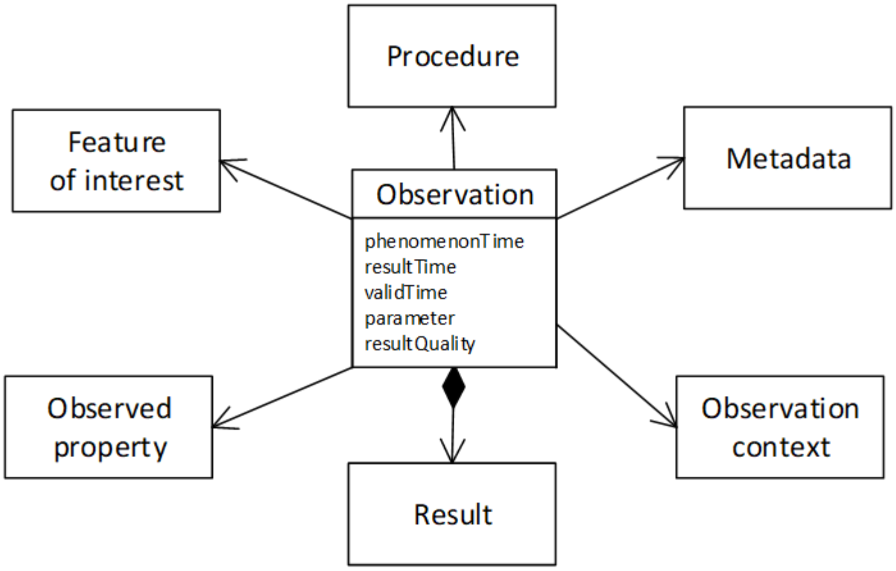

Fig 1: Basic UML class diagram showing a simplified model of ISO 19156 Observations and measurements.

The Observation, in addition to having relationships with other objects such as the abovementioned Procedure, Observed property, etc. has some properties of its own, such as:

- phenomenonTime: Time / time interval when the phenomenon of interest happened.
- resultTime: The time when the result was obtained, which for practical purposes is the same as the phenomenonTime for a temperature sensor, but could be significantly different in the case of, say, a laboratory test.
- validTime: Time interval during which the result is valid, such as in the case of a forecast that will eventually be replaced by another.

- parameter: Data needed to interpret the Result, e.g., height above ground of an air temperature measurement, or the depth below ground of a soil water content measurement.
- dataQuality: Metadata that describes the fitness for usage of observations data (e.g., measures of geographic precision of the latitude/longitude data of a field scouting observation, or a measure of completeness of a dataset purporting to show crop stand count observations every 5 meters in a field.)

Part 2 of the ISO 7673 standard is primarily occupied with how to represent the meaning of the abovementioned Observation and related objects in a clear, compact and manageable way, using controlled vocabularies whenever possible. The basic underlying principle is that **different stakeholders capture (and need) different levels of detail in their observations and measurements, given the great variety of their processes, needs and circumstances**. This has several implications, and led to specific design decisions:

- At its most basic, an Observation can be represented as a key-value pair, where the key (called an “observation code”) represents a combination of feature of interest, observed property, etc. The value is as described above (e.g., an encoded form of the “42 degrees Celsius”). In practice this would also be accompanied by a timestamp, and possibly a latitude / longitude or a reference to a field, etc.
- Additional meaning can be associated to Observations to supplement the meaning of the observation code (e.g., a species identifier to provide additional information supplementing a generic observation code representing the idea of a species count used in crop scouting.
- These additional componentized particles of meaning, are called “code components”.
- The precise balance of what meaning should be included as part of the observation code definition and what should be added to observations will depend on the application. The standard provides examples, and the project team will produce additional guidelines soon after publication.

Irrigation Operations

The goal of Part 3 is to create a practical data model for communicating the planned and actual placement of water and associated products (e.g., for chemigation/fertigation). There are a great variety of irrigation system types available to growers. These systems vary both in their design and in their management. The PAIL standard intends to be relevant to any system type. This requirement means we must have an abstraction that can be usefully applied to any system type.

In the context of ISO 7673-3, irrigation systems are comprised of a collection of one or more components for delivering water to a given area. These components can be stationary, moving in a plane, or rotating around a point. The ISO 7673-3 data model contains abstract specifications of these components as they relate to documenting when and how much water is, was, or should be applied to a particular area. The fundamental abstractions are the Sections and the IrrItem Class.

A section is a contiguous portion of an irrigation system, irrigated using the same method (e.g. sprinklers, tape, furrow, etc.), and with the same nominal application rate. Sections are defined using the SystemSectionSetup class and irrigations are documented using the SectionFlow class. Organization and management are further refined using the Block and Set classes.

> **SystemSectionSetup**: In the case of abstract, hardware-independent recommendations and work orders, SystemSectionSetup describes the area to be irrigated. It is acceptable for a system to have only one section. The SystemSectionSetup defines a subdivision of the field such that recommendations, planning, and reporting of water use can be expressed accurately and flexibly. Sections may be static (fixed over time) or dynamic (moving over time), or both.

Each type of irrigation system has different physical constraints that will determine how to define the SectionFlow and IrrItem objects in irrigation documents. Additionally, ISO 7673-3 defines two concepts that will help facilitate documenting water use with irrigation systems.

Block: A subdivision of an irrigation system that a) covers a portion of the total area irrigated and b) can be controlled independently of other blocks. The Block concept corresponds roughly to the concept of a block in drip and solid set systems. It is a refinement of the Section concept in that flow to the block is controlled (usually via a valve) independently from the other blocks.

Set: A collection of one or more blocks within the same irrigation system that are irrigated together. The blocks associated with a set may change during an irrigation season.

A Set is an emergent property of the system's management. A Block is a property of the system's design. The application rate within a given Block is determined by the design of the irrigation system. The depth of application is determined by the management of the Set. The definition of these two terms depends on the system type.

IrrItem: An IrrItem represents a single application of water. An IrrItem contains information about when, where, and how much water was or should be applied in a particular field. For a pivot, a single IrrItem corresponds to a single (possibly partial) rotation of the whole machine. For other system types, an IrrItem corresponds to a wetting of a specific area of the field. Each IrrItem contains a sequence of SectionFlow objects.

IrrCollection: A collection of one or more Irrigation Items. The IrrColl class maintains a hierarchical relationship with IrrItem. Both classes have several identically named property definitions. Properties specified by an instance of IrrColl apply to each of the IrrColl's child IrrItem objects unless the IrrItem contains a different specification. When the child IrrItem objects have values for the members, the child's values take precedence.

IrrItem and IrrCollection implement a hierarchical relationship with several identically named property definitions. Properties specified by an instance of IrrColl apply to each of the IrrColl's child IrrItem objects unless the IrrItem contains a different specification. When the child IrrItem objects have values for the members, the child's values take precedence. This hierarchical structure and property precedence allow space-efficient expression of irrigation records.

SectionFlow: Each IrrItem contains one or more SectionFlow instances. A SectionFlow describes how water and/or product was applied for a section. Each SectionFlow instance is associated with a SystemSectionSetup. A single SectionFlow represents a single wetting of an area of the field and may include a spatial footprint, time scope, Set membership, and water source.

In the Standard irrigation documents, the SectionFlow, IrrItem, and associated objects appear in a hierarchical structure, as shown in figure 2 below. The Reference Document, Irrigation Document, and Setup Document are shown as blocks containing sub-blocks corresponding to the various objects that make up the document. Arrows indicate which objects refer to objects in parts of other documents. For example, the Section Flow object in the Irrigation Document refers to the Section object in the Setup Document. Relationships among document elements. The arrows indicate links between the document elements.

There are several other classes defined in 7673-3 that relate to product application, water sources, end guns for pivots, roles & responsibilities, and provenance of the setup information. Details of these classes are beyond the scope and space limitations of this paper.

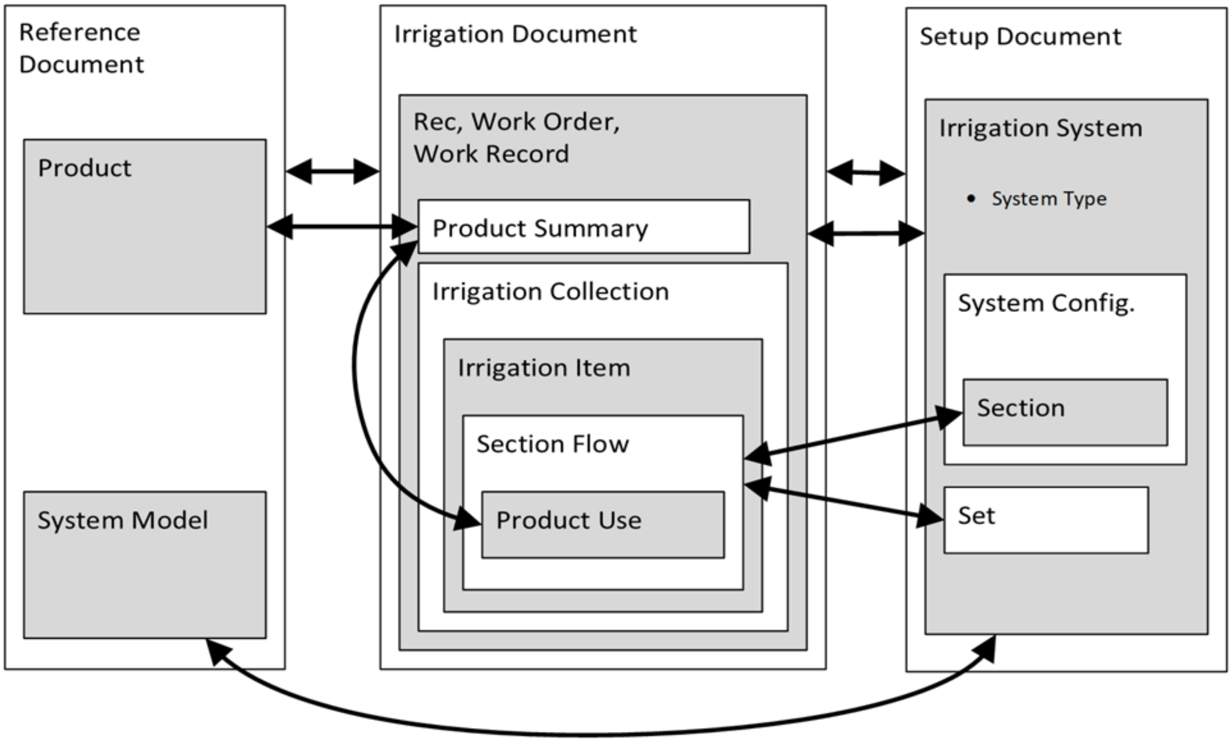

Figure 2 Conceptual view of the relationships between the Reference, Setup, and irrigation data documents.

Different Kinds of Irrigation systems

The abstractions defined above are not sufficient, by themselves, to describe irrigation records. ISO 7673-3 includes clauses that specify how to apply the abstractions to specific types of irrigation systems. This section describes different kinds of irrigation systems using the concepts defined above. The standard document provides more detailed descriptions.

Center Pivot

With a center pivot irrigation system, water is applied by sprinklers distributed along the length of the system, and the whole system moves during the application. Depending on the abilities of the irrigation system, the sprinklers may be controlled individually or as a group of sprinklers. This group of sprinklers or contiguous wetted portion is called a Section. If the group of sprinklers covers the full length of the irrigation system, there is one section, and its inner distance is the distance from the pivot center to the first sprinkler or innermost wetted area. Similarly, the outer distance is the distance from the pivot center to the last sprinkler or outermost wetted area. The geometric interpretation of Section is illustrated in figure 3 below. When there are multiple groups of sprinklers, each section is defined as the distance of the first sprinkler or wetted area of the section (measured from the pivot's center) to the distance of the last sprinkler or wetted area of the section. Sections are a basic unit of water delivery in this standard. In the simplest case, a pivot would have only one Section definition. If the pivot makes one complete revolution and all the operating parameters remained constant (i.e., no speed changes or flow variations), then the irrigation document would contain a single IrrColl, containing a single IrrItem which itself would contain a single SectionFlow object. Pivots, and Linear Move, do not use the Set and Block concepts.

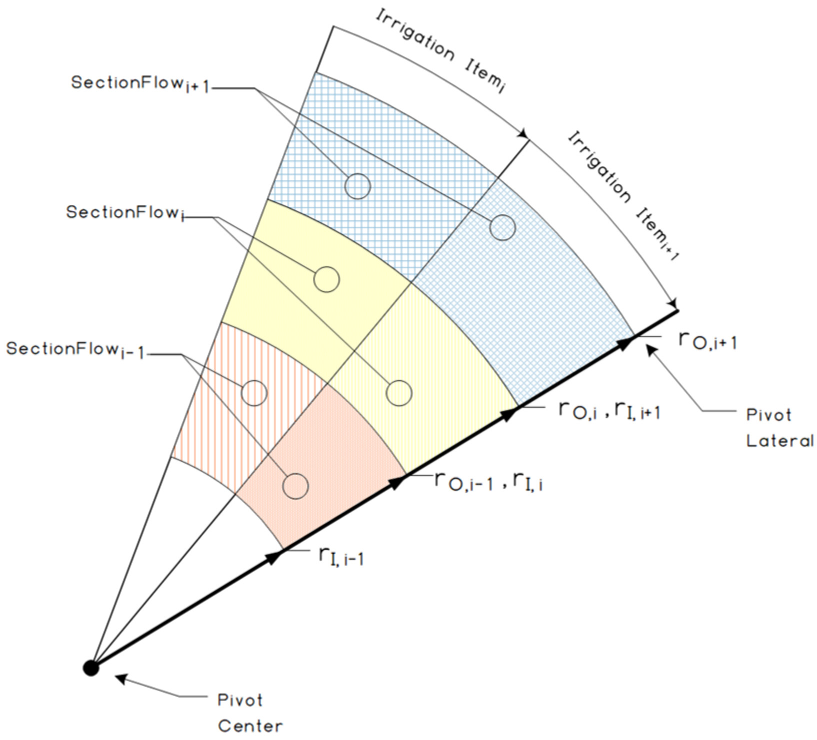

Figure 3: Six SectionFlow areas associated with three adjacent Section definitions and two adjacent IrrItems

Linear Move Systems

Linear Move (also known as Lateral Move) irrigation systems use equipment similar to Pivot systems but the Linear Move system moves in a linear rather than circular pattern. Newer Linear Move systems are also steerable and can follow a predefined, non-straight path (Figure 4).

The following constraints apply to Linear Move systems

- Sections have the same interpretation that Pivot systems use
- Section numbering/ordering begins with the Section closest to the hose reel cart or drafting inlet
- IrrItems shall have non-overlapping temporal scope (i.e., non-overlapping IrrItem instances in the same IrrCollection)
- IrrItem numbering/ordering begins with the earliest item
- SectionFlow instances relate to and reference SectionSetup instances in the same way that Pivots do
- SectionFlow instances which are not rectangular shall use the SectionFlow’s PolygonCoverage property to document the area covered by the irrigation system

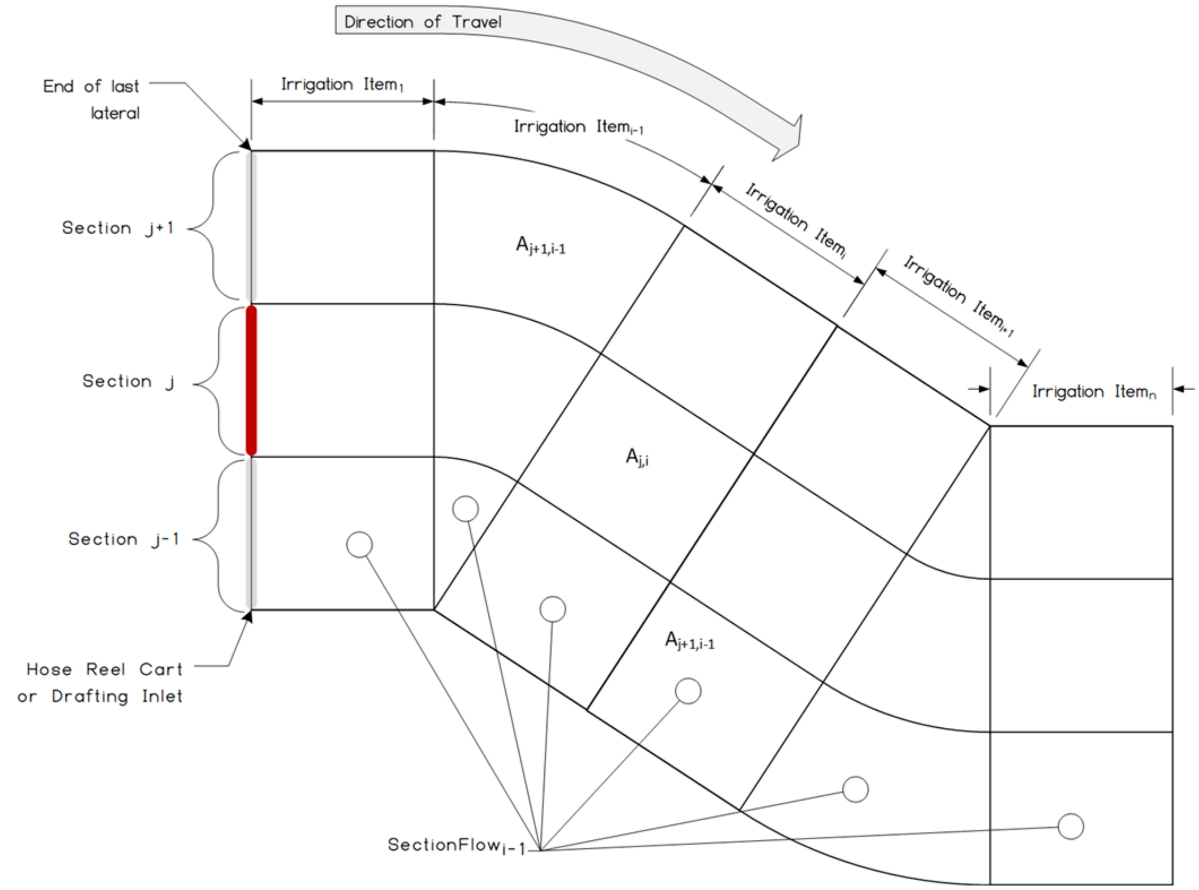

Figure 4 Schematic view of a Linear Move irrigation system following a curved path

Drip Irrigation

Drip is a form if irrigation that combines stationary emission devices and low application rates (per emitter) to achieve high application efficiency. Within the context of Drip Irrigation systems, Block and Set have the following interpretation:

> **Block**: A subdivision of a drip irrigation system that enables irrigation of a portion of the total area irrigated by the system and can be controlled independently of other blocks.
> **Set**: A collection of one or more blocks within the same irrigation system that are irrigated together. The Blocks associated with a Set may change during an irrigation season.

Figure 5 below illustrates Blocks in an example irrigation system. This example system has a rectangular area subdivided into six parts, where each part has its own valve controlling flow to that part. Each one of these parts, controlled by a single valve, is a Block in the context of 7673. Each Block will have one SectionSetup instance in the setup data. Each of these SectionSetup instances correspond 1-to-1 to the Blocks in the physical irrigation system.

The following constraints apply to drip irrigation systems:

- Each Block shall have exactly one SectionSetup
- SectionSetup shall use the SpatialFootprint property
- SectionFlow instances corresponding to a single Set shall be grouped in a single IrrItem instance.

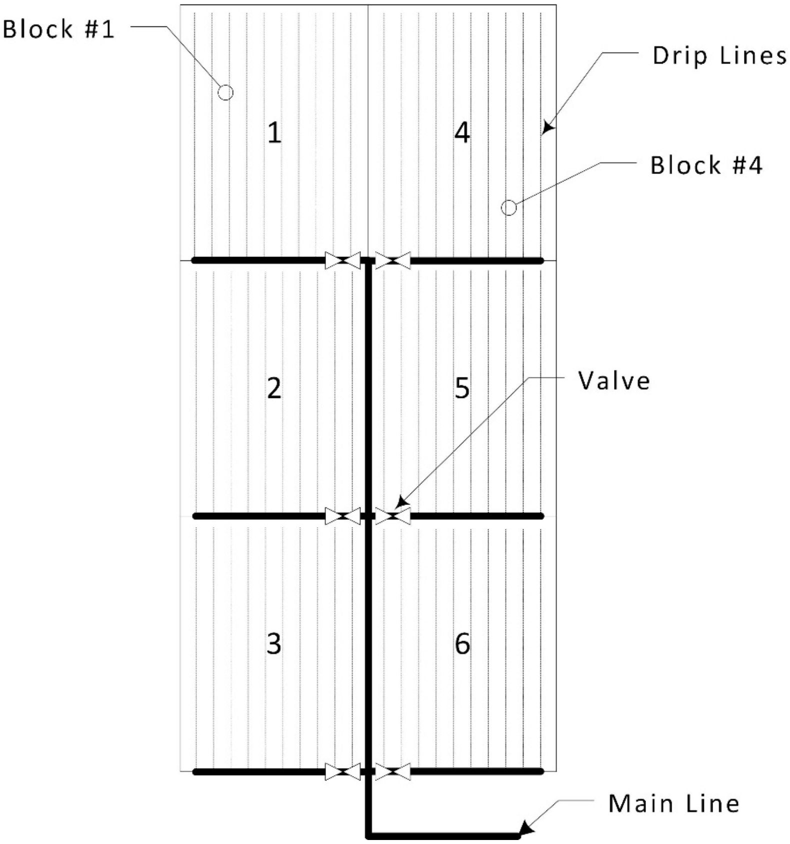

Figure 1 Schematic diagram of a Drip irrigation system having six Blocks

Wheel Lines and Hand Lines

Irrigation with Wheel Lines typically involves one or more portable lines with multiple sprinklers attached. The lines are moved periodically and typically in a repeating pattern. The line is attached to a hydrant (connection point) and the hydrant is stationary. For some Hand Lines, the hydrants are temporary but their location does not change during the irrigation season. For the purposes of this standard, Wheel Line and Hand Lines are equivalent.

Surface Irrigation

Surface irrigation is modeled similarly to drip systems in that it involves sections with shapes that are invariant over the course of an application of water, using a polygon representation for the geographic extent of the sections (rather than a radial shorthand usable in pivots).

In general (with the exception of paddy irrigation), the desired and actual applications of water are, as in the case of drip systems, specified in terms of a desired volume or depth of water; i.e., a representation centered on mass balance.

The following interpretation of Block and Set apply to surface irrigation (See figure 6):

> **Block**: A subdivision of the total area of a field, irrigated by the system, and which can be controlled independently of other blocks. Control in this context refers to any mechanism that allows the irrigator to alter the flow of water, such as gates, valves, check structures, temporary dams, temporary ditches, and siphon tubes.
> **Set**: A collection of one or more blocks within the same irrigation system that are irrigated together. The Blocks associated with a Set may change during an irrigation season.

Paddy Irrigation

Paddy irrigation presents a special case of surface irrigation. While a paddy system can still be divided into one or more sections, the amount of water to apply is specified not necessarily in terms of volume, but in terms of a depth goal. In other words, water is added or removed until the specified goal is reached. This goal can be specified using a model analogous to that of the observations & measurements used in ISO 7673-2; in other words, a key-value pair where the key represents the meaning of the observation (e.g., depth of the water column), and the value is the numerical depth along with a code denoting the unit of measure.

The SectionFlow class has a property, waterLevel, which enables specification of the depth in the paddy. In a Recommendation or WorkOrder, the waterLevel value represents the recommended or prescribed water level in the paddy. In a WorkRecord, the waterLevel value represents the average waterLevel at the end of TimeScope of the sectionFlow's parent IrrItem. Variable water level shall be documented with multiple IrrItem instances, each having non-overlapping timeScope, and having instances of sectionFlow with waterLevel values.

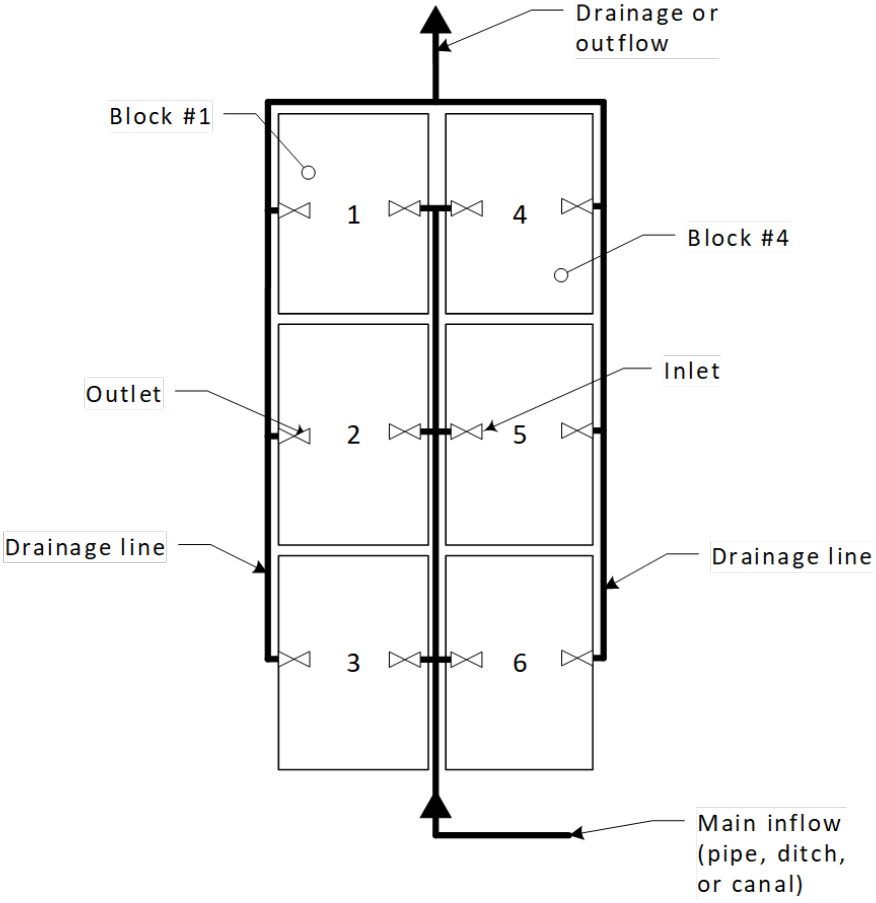

Figure 6. Example schematic diagram of a paddy irrigation system. Note that while generic valves are shown on the inlet and outlets (using ISO 15081 symbology), a head gate would be equally appropriate. The subdivisions of the field can apply in cases of open cha

Solid Set

Solid Set systems (See fig. 7) have been defined in various standards such as EN 13742-1. For the purposes of this standard, a solid set system has the following features:

- The system components (particularly the sprinklers) do not move during or in between irrigations. The system components may move in between irrigation seasons.
- The emission devices are typically sprinklers which distribute water as droplets over distances significantly larger than micro-sprinkler systems (as defined in ISO24120-3).

These two features differentiate Solid Set systems from Hand Lines (which do move between irrigations), and from drip systems which have much smaller emission rates per emitter. Solid Set systems may be designed such that portions or subsets of the field can be irrigated; much the same way drip irrigation systems do.

The figure below shows a schematic view of a Solid Set system having two sets. The hatched areas delineate the managed area relevant to documenting irrigation. Typically, the field boundary is the managed area. However, given the semi-indeterminate nature of the wetted area (i.e., lack of full sprinkler overlap at the block boundaries), Solid Set systems may use the setup data to define the field boundary, and the SystemSectionSetup's spatial boundary property to define the spatial extent of the wetted area.

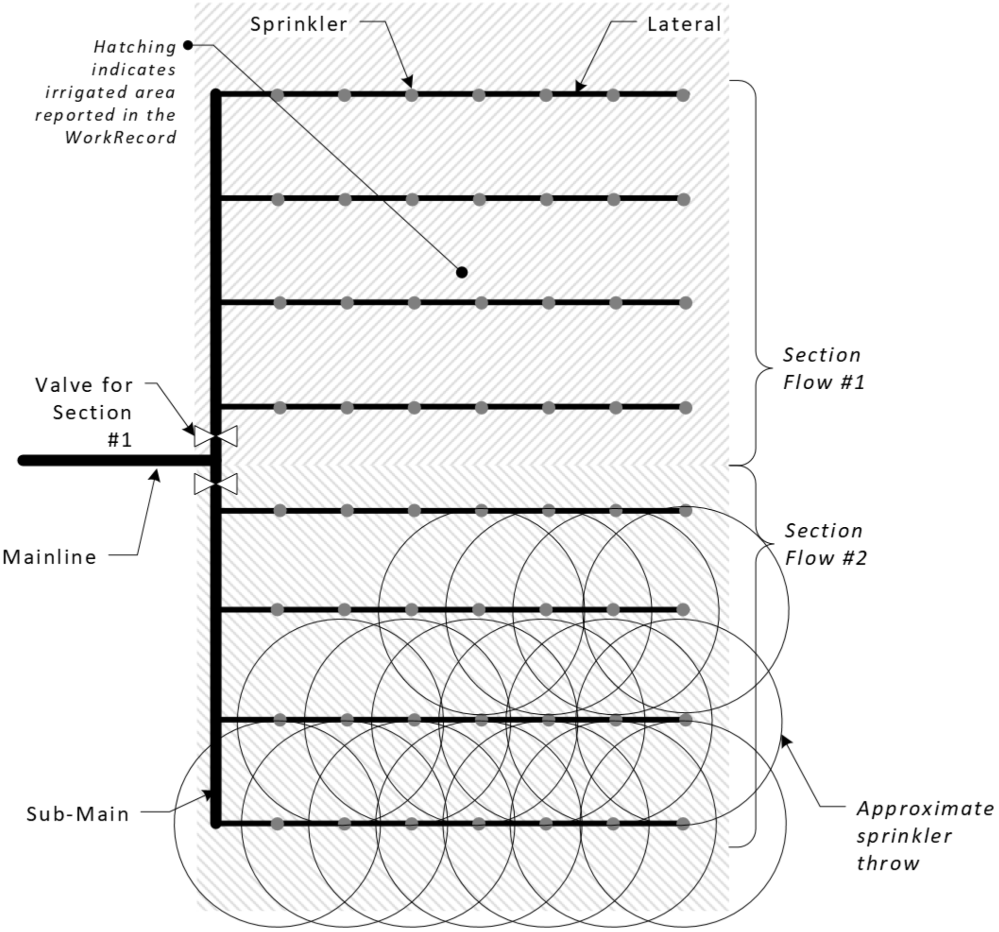

Figure 7. Schematic view of a Solid Set irrigation system

Travelers

ISO 8244-1 describes Traveller irrigation machines (See fig. 8). For the purposes of ISO 7673-3, Travelers include those systems defined in 8244-1, and systems with the following attributes:

- The emission device(s) is/are mobile during the irrigation event
- The emission device(s) follow a prescribed or planned path during the irrigation operation.
- The emission device(s) move continuously (or periodically with short intervals) during water application.

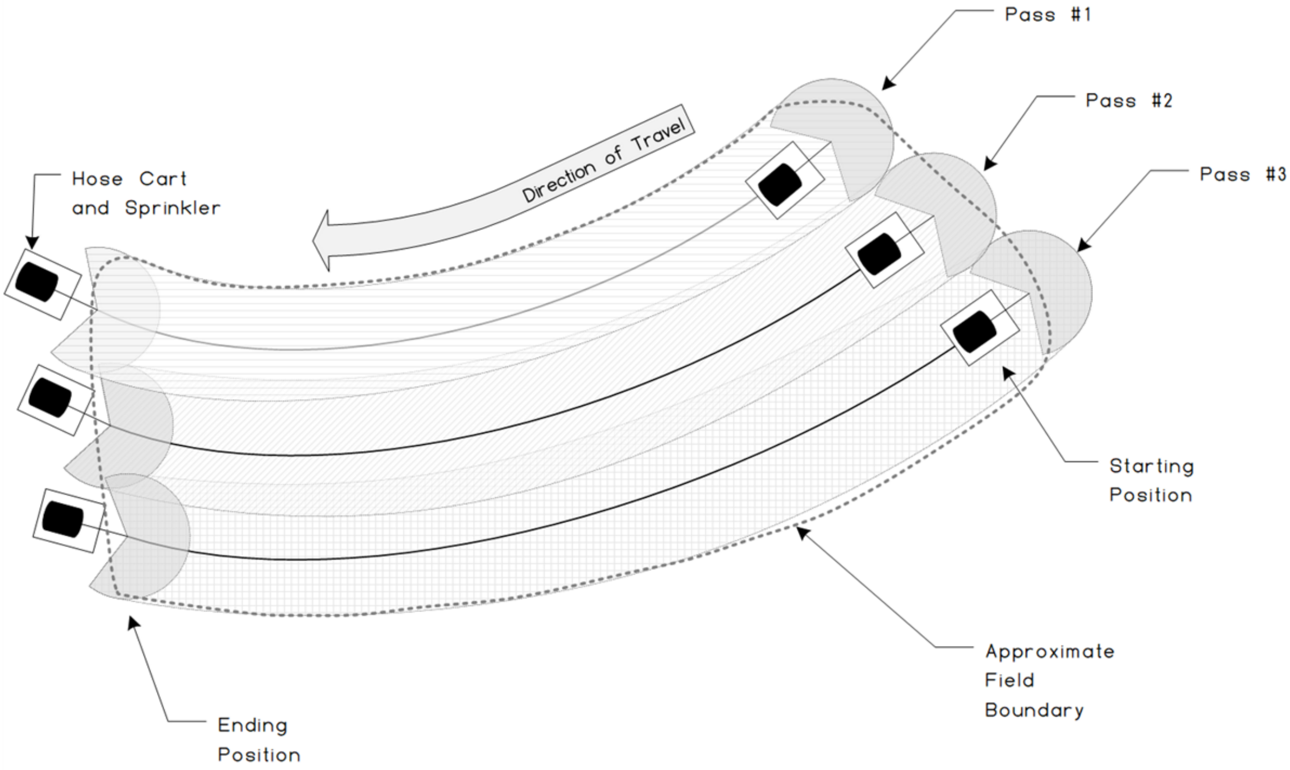

Figure 8. Traveller schematic diagram showing three passes of a single gun.

Recent technological advances (low-cost RTK GPS) have enabled semi-autonomous hard-hose traveller irrigation systems. While Traveller systems are generally not automated, newer semi-autonomous systems have performance characteristics that will benefit from standardized data exchange.

Accommodating Different Realities: Paddy irrigation

Paddy irrigation requirements are often goal-based, where the goal is a desired water level in the paddy, and the goal has a time frame desired for achieving the targeted water level. The SectionFlow class (IrrItem) has a member called waterLevel that enables this method of irrigation.

The following example illustrates (see figure 9 below) the use of the waterLevel property and the goal-based approach that is typical of paddy irrigation. Consider a 0.3 Ha field that has a starting water level of 5 cm. An expert recommends that the water level increase to 10cm over the next 24 hours. The field's manager issues a WorkOrder indicating that the desired water level is 10 cm and the operator wants to achieve this level in 24 hours. The field telemetry system executes this order and produces a WorkRecord. The WorkRecord shows the water level in 8-hour increments, with an ending water level of 10 cm. The following figure shows an abbreviated version of the documents that would result from this process.

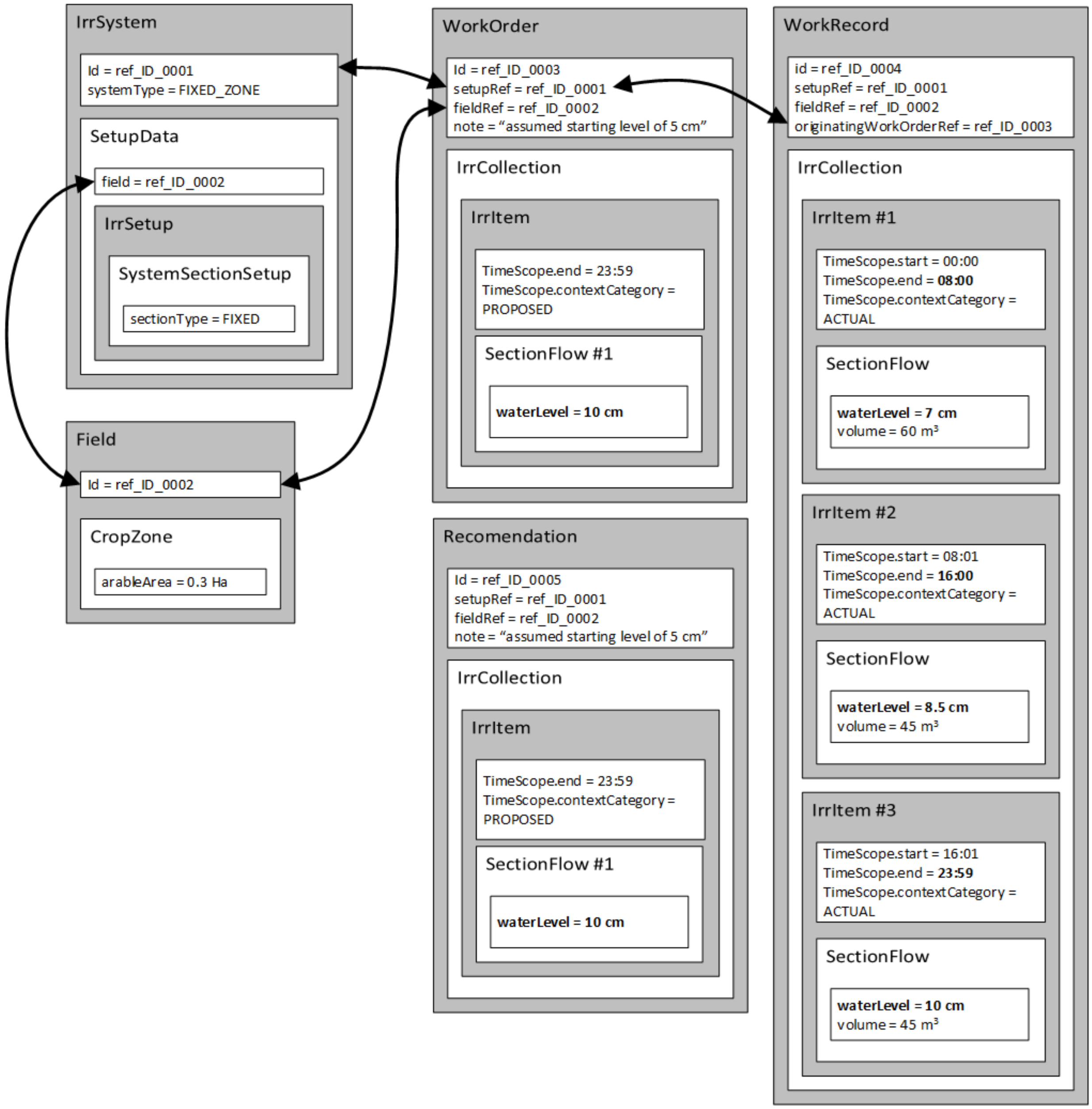

Figure 9. An abbreviated example of a Recommendation, Work Order, Work Record, and relevant setup data for Paddy irrigation. Note the use of the waterLevel property.

Discussion

Interoperability standards are necessary but not sufficient; implementation, communications and stakeholder engagement are necessary too.

An example of the value of integration is found in the study by Jamal et al. (2023), who examined the management benefits of incorporating weather forecasts into irrigation scheduling. This study integrated past water use and weather forecasts to produce optimal irrigation recommendations. Unsurprisingly, using weather forecasts instead of non-SIS scheduling techniques decreased water use and improved yields in dry years.

Work like this involves a major effort of procuring data from different sources, integrating it into a scheduling tool, and training and supporting users to use it effectively. While having interoperability standards makes it *possible* to solve the scheduling problem at scale, it is far from sufficient for success. Engaging technology providers, clearly demonstrating the value proposition, and providing them with resources to train and support end users is a necessary and often overlooked part of standards implementation.

Semantics and shared meaning are important

Data interoperability goes beyond having different actors within a data exchange process use the same data format (syntactic interoperability). It also includes them representing the meaning of data within that format in an unambiguous way that can be interpreted the same by all the actors (semantic interoperability). Code lists and other controlled vocabularies are a common way of enabling semantic interoperability; if all the actors in the data exchange process have access to the controlled vocabularies and use the same codes in the same way to represent information, then meaning can be preserved.

The three parts of the ISO 7673 series use controlled vocabularies. Part 1 presents the ContextItem system as a tool to attach geopolitical context dependent data (e.g., an attribute specific to one jurisdiction, such as the EPA number for a product) to objects without cluttering the underlying data model with information that may be irrelevant to some users. Similarly in Part 2, observation codes and code components are useful only when all parties have access to their definitions. Part 3 uses controlled vocabularies in multiple places, primarily to provide metadata to help understand the configuration of an irrigation system (e.g., an enumerated list of the position of the pressure sensor on a pivot).

Management is something a grower does. Managing irrigation via principled decision making involves a new tool: a decision support system (DSS). While DSS are not new, their use by growers has been very limited. Introduction principled decision making via a DSS changes irrigation management from something you do to something you buy. By having the tool do the work of data transfer, analysis, and actuation, management becomes a less time-consuming process. Using a quantitative method (i.e., scientific irrigation scheduling) results in water management that is more accurate and predictably efficient.

Relation to environmental reporting / documenting supply chain emissions

Informed consumers want to know where their food comes from and how it was produced. Documenting the impact of production is possible from a purely technical standpoint. In practice, however, documenting all the steps and actions from primary production to final sale is still daunting. A significant part of the task involves transferring sufficient information to each entity in the value chain such that subsequent recipients can perform meaningful calculations with the data. Simply possessing the data is not sufficient. The data must also include technical specification of the data's meaning, its provenance, and its ownership. The ISO 7673 series is a step towards fully documenting the agricultural value chain.

International standards need big tables

It's often said that standards are written by, and represent the interests of, those seated around the table. This introduces the need for due diligence to ensure that a representative set of stakeholders is seated at that metaphorical table, especially if the intent is to produce an international standard. As a clear example, the USA-based team initially drafting the ISO 7673 series included what they thought was sufficient support for drip and surface irrigation systems. The proposed solutions were later greatly improved, however, through discussion with delegations from Israel and Japan, who were very familiar with multiple use cases in arid and humid paddy environments, respectively.

The work never stops.

There are many different kinds of irrigation systems worldwide. Management of these systems varies both by system type and by region. For example, management of pivot systems is very different in humid regions relative to arid regions. New system automation technologies emerge constantly. These technologies introduce new concepts that affect how we implement and communicate management decisions. These changes in technology, combined with changes in management, create an ever-evolving data landscape. Because of the data-driven nature of much of this work, ongoing revisions to the standard will be necessary as new knowledge and requirements are revealed.

References

Adhikari, D., Berger, A., AgSense, L., Huron, S., Berne, D., Ferreyra, R. A., Hillyer, C., Melvin, S., Nef, N. B., and Penning, T. (2016). “Precision Ag Irrigation Language (PAIL) Project.” *2016 Irrigation Show & Education Conference*, Irrigation Association, Las Vegas, NV.

Applegate, D.B., Berger A.W., Berne, D.T., Bullock, R., Craker, B.E., Daggett, D.G. (2016). “Toward Geopolitical-Context-Enabled Interoperability in Precision Agriculture: AgGateway's SPADE, PAIL, WAVE, CART and ADAPT.” A paper from the Proceedings of the 13th International Conference on Precision Agriculture, July 31 – August 4, 2016, St. Louis, Missouri, USA

Craker, B.t, Danford, D.D., Ferreyra, R.A., Nelson, K., Rhea, S.T., Stelford, M.W., Wilson, J.A. (2018). “ADAPT: A Rosetta Stone for Agricultural Data.” A paper from the Proceedings of the 14th International Conference on Precision Agriculture, June 24 – 27, 2018, Montréal, Quebec, USA

ISO/DIS 7673-1 (2024) *Agricultural field operations data — Part 1: Core concepts*

ISO/DIS 7673-2 (2024) *Agricultural field operations data — Part 2: Observations and measurements*

ISO/DIS 7673-3 (2024) *Agricultural Field Operations data — Part 3: Irrigation Operations*

Jamal, A., Cai, X., Qiao, X., Garcia, L., Wang, J., Amori, A., & Yang, H. (2023). Real-time irrigation scheduling based on weather forecasts, field observations, and human-machine interactions. *Water Resources Research*, 59, e2023WR035810. https://doi.org/10.1029/2023WR035810