

ANSI/ASABE S632-3 JUN2018 (R2022)
Precision Agriculture Irrigation Language: Irrigation System Operations



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Precision Agriculture Irrigation Language: Irrigation System Operations

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0 Introduction

Part 3 of the Standard pertains to irrigation operations, i.e., the activities associated with the application of water with an irrigation system. It focuses on management-level communications and record-keeping. The operations data set is based around a set of Core Documents: a Recommendation, which describes a suggested course of action; a Work Order, which describes a desired course of action; and a Work Record, which describes what actually happened. This work is based on, and extends, the ISO11783-10 standard for communications between agricultural machinery and FMIS (ISO, 2015).

Software developers and others using this part of the Standard should read, and be familiar with the Core Concepts presented in Part 1 of the standard, including the following:

- Business Process Models that are used to describe the flow of data within an integrated irrigation system
- The actors and their role(s) in the process
- Core Documents and their relationships
- The use of unique identifiers and Compound Identifiers for objects that are used by reference in another object
- How the standard captures the concept of time in irrigation events
- Specifying Reference, Setup and Configuration data

The sections titled Reference Data, Setup Data, and Irrigation Data describe the classes that compose messages in the Standard:

- UML class diagrams show all the properties
- List with precise description of the properties of each class
- Implementation guidelines

Annex A Contains a series of examples that represent common use cases covered by the standard

Annex B Contains an XML schema implementation of the object model described in the preceding sections.

Annex C Contains a series of XML examples representing common use cases covered by the standard.

1 Purpose and Scope

The purpose of this part of the Standard is to present an object model and reference XML serialization schema to represent the specification and reporting of irrigation water and product applications in an irrigation system. The scope includes planning and preparation phases (represented by documents called Plan, Recommendation and Work Order) as well as the recording of as-applied water and products (known as a Work Record). The scope of this document does not, however, include representing the Observations and Measurements that drive

tactical decision-making in irrigation (and the creation of Recommendations and Work Orders); that material, corresponding to an irrigation-specific implementation of the ISO 19156 standard, is covered in Part 2 of this standard. This standard should enable a developer to unambiguously represent the data being communicated in various parts of the farmer's business process associated with irrigation field operations in terms of a set of classes based on the ISO 111783 standard.

The Standard is meant to support the exchange of data. The classes, data formats, and structures described herein are not meant to indirectly specify internal structure or the object model of an Farm Management Information System (FMIS) or similar system. While it is easy to draw parallels between an object model and a database schema, the object model defined here is not specifically meant to be construed as a database schema or as the internal structure of an FMIS.

The standard does not specify any type of “summary” report. This is intentional. The information contained in a collection of standard-compliant documents will be sufficient to create a summary of irrigation applications. Actual summarization of irrigation requires aggregation, and the method or scope of aggregation is often derived from specific reporting requirements. This standard is neutral with regard to reporting requirements because these requirements are typically derived from a regional, basin, or administrative unit scale and are, therefore, out of scope.

It is important to note that standard-compliant documents are intended for documenting operation or use of equipment, not the design of equipment. Many characteristics of an irrigation system are relevant for documenting the system's design but not necessarily for documenting its use. For example, the pipe diameter of a pivot lateral is typically included in its specification. Documenting how much water the pivot applied does not require knowledge of the pipe diameter. Documentation of engineering design is out of scope for the Standard.

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For updated references, the latest edition of the referenced document (including any amendments) applies.

ISO/FDIS 6709 Standard representation of geographic point location by coordinates

ISO 8601 Data objects and interchange formats — Information interchange — Representation of dates and times

ISO/IEC 9834-8 Information technology — Procedures for the operation of object identifier registration authorities — Part 8: Generation of universally unique identifiers (UUIDs) and their use in object identifiers

ISO 11783-10 Tractors and machinery for agriculture and forestry — Serial control and communications data network — Part 10: Task controller and management information system data interchange

ISO/IEC 13249-3:2011 Information technology — Database languages — SQL multimedia and application packages — Part 3: Spatial (WKT)

ISO 19109 Geographic information — Rules for application schema

ISO 19112:2003 Geographic information — Spatial referencing by geographic identifiers

ISO 19156:2011 Geographic information — Observations and measurements

ISO/IEC 19510:2013 Information technology — Object Management Group Business Process Model and Notation

ISO/IEC 19757-3:2006 Information technology — Document Schema Definition Language (DSDL) — Part 3: Rule-based validation — Schematron

ISO 22006:2009 Quality management systems — Guidelines for the Application of ISO 9001:2008 to crop production

3 Definitions

3.1 data exchange: A transfer of information between two or more entities where the information is typically in the form of electronic documents.

3.2 data provider: A person or entity responsible for collecting, storing, and providing information used in **data exchange**.

3.3 grower: A person or entity responsible for managing agricultural production.

3.4 irrigation collection: One or more **irrigation items** which together document water application on a particular field.

3.5 irrigation item: information needed to document when, where, and how much water was or should be applied on a particular field.

3.6 irrigation recommendation: A document containing one or more **irrigation collections** which specify when, where, and how much water should be applied.

3.7 irrigation setup: The arrangement and configuration of irrigation equipment at a particular time.

3.8 irrigator: A person or entity responsible for managing the application of water for agricultural production.

3.9 message: A package of information (typically a document in electronic format) exchanged at a particular time for a particular purpose wherein the information pertains to the execution of a particular agricultural operation.

3.10 section: A contiguous portion of an irrigation system, composed of one or more sprinklers or water sources, wherein the application rate is the same along the contiguous portion.

3.11 section flow: An amount of water emitted from a **section** at a particular time and at a particular location.

3.12 work order: A set of instructions, given by someone with authority for a specific course of action to take. An irrigation Work Order describes the amount of water to apply to a given piece of land over a specific time period.

3.13 work record: A document that describes what actually happened while performing the field operation. It may differ from the Work Order because the operator performing the field operation may have had to make adjustments to particular conditions (e.g., suspended the operation because the ground was too wet and returned the next day).

4 The Management Process

The standard is built around an assumption that irrigation is managed and that the management can be defined by a process. This assumption is derived from the business process that is typical of irrigation management service providers and irrigation managers at more extensive operations. All the classes and objects defined in the standard are based on business practices. Agronomic processes are not ignored but instead are embedded in the business processes. The BPMN defines all of the actors, processes, and messages that are relevant to the irrigation management process.

4.1 The In-Season Management Process

Figure 1 shows a Business Process Modeling Notation diagram of the irrigation management process. This diagram is also shown in Part 1 of this standard which contains a discussion on the content and meaning of this diagram. Part 1 also includes a primer on BPMN diagramming. A more detailed discussion is presented here.

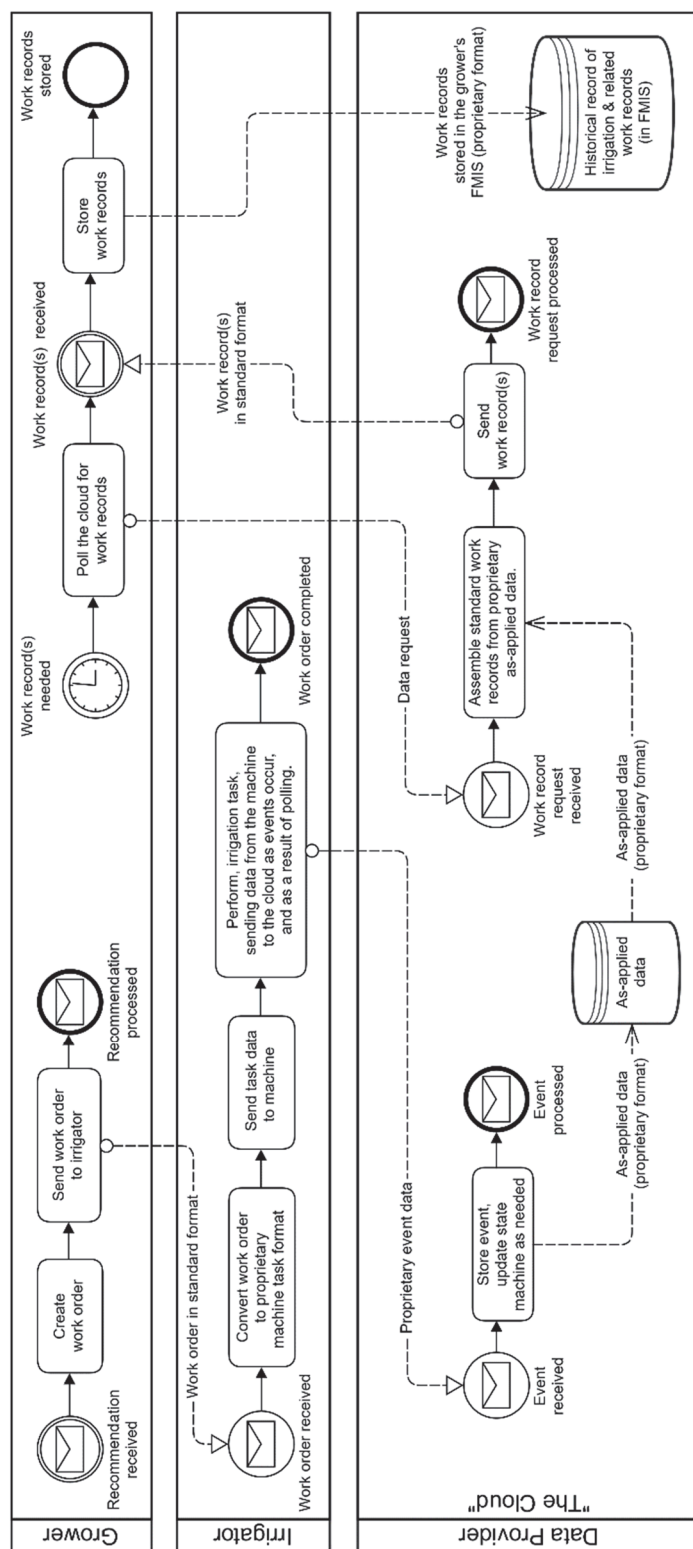


Figure 1 – The BPMN diagram for in-season management operations

In the figure, the dashed lines represent messages that actors exchange during the process of implementing irrigation during the growing season. Not all the messages are in the Standard format. Non-standard messages are excluded from the standard because they include proprietary information. Non-standard messages are indicated as such in the diagram. The standard does not stipulate how to implement the processes. It only presumes that these processes occur and that the messages are passed. Some aspects of the processes may be indirectly limited by constraints of the context of the messages. While it is technically possible for the message exchange to happen manually (i.e., by paper or verbal exchanges), the standard assumes that the message exchange is facilitated by an FMIS or another software system. Finally, the diagram does not precisely specify the standard, only the context in which the actors exchange messages.

4.1.1 Grower Process: Work Record request/received

- The BPMN begins with receipt of a recommendation. The standard assumes that someone with expertise created the recommendation and did so using field measurements that indicate a need for irrigation. Part 2 describes the process by which recommendations are created.
- The Grower creates a Work Order based on the Recommendation. The Work Order may differ from the Recommendation based on the Grower's knowledge or preferences
- The Grower then transmits that Work Order to the Irrigator, the person in charge of performing the operation.

For small or mid-sized farms, the Grower and Irrigator is often the same person. In that scenario, the message exchange is primarily symbolic. The Work Order represents the decision by the Grower.

4.1.2 Irrigator Process: Work Order Received

- The process begins when an Irrigator receives a Work Order.
- The Irrigator then uses the Work Order to set up the irrigation task. The exact nature of this step will depend on the hardware involved: it may range from sending the standard-format Work Order in electronic form to a telematics system, to using the information on a printout of the work order to guide the manual programming of an irrigation system panel. The specifics of what happens at this step are not in scope of this standard.
- The Irrigator starts the machine and performs the task.

4.1.3 Data Provider Process: Receive Event Data

- While the machine operates, it will generate a series of events (e.g., machine is on and applying water, the machine turns off, there is low pressure or other error conditions, etc.)
- The event data is assumed to be logged by a Data Provider, who will translate the proprietary sequence of events into standard-format Work Records.
- The process begins when an event is received by the Data Provider.
- The Data Provider stores the event data on its own, proprietary state machine database. The specifics of the data involved are outside the scope of this standard.
- The process ends after the storage operation is complete.

4.1.4 Grower Process: Work Records Needed

- The process begins when the Grower decides that he/she needs Work Records
- The Grower sends a request to the Data Provider
- The Data Provider assembles the Work Records collected during execution of the Work Order and sends them to the Grower. The messages may also include Work Orders with status updates for work that is still ongoing.
- After receipt of the Work Records, the Grower may choose to store these records in a proprietary database. The Data Provider who stores these records is not necessarily the same provider that generated the records.

5 Central Concepts

This section describes fundamental concepts that are used throughout the standard. The concepts presented in this section manifest in the standard as class definitions. The following sections contain the details of each class,

its attributes, relationships, and constraints. This section introduces each class as a concept and describes its purpose.

5.1 Describing Irrigation Systems and their Component Parts

Irrigation systems comprise 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.

With a center pivot irrigation system, water is applied by sprinklers that cover some length of the total system. 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 2. 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.

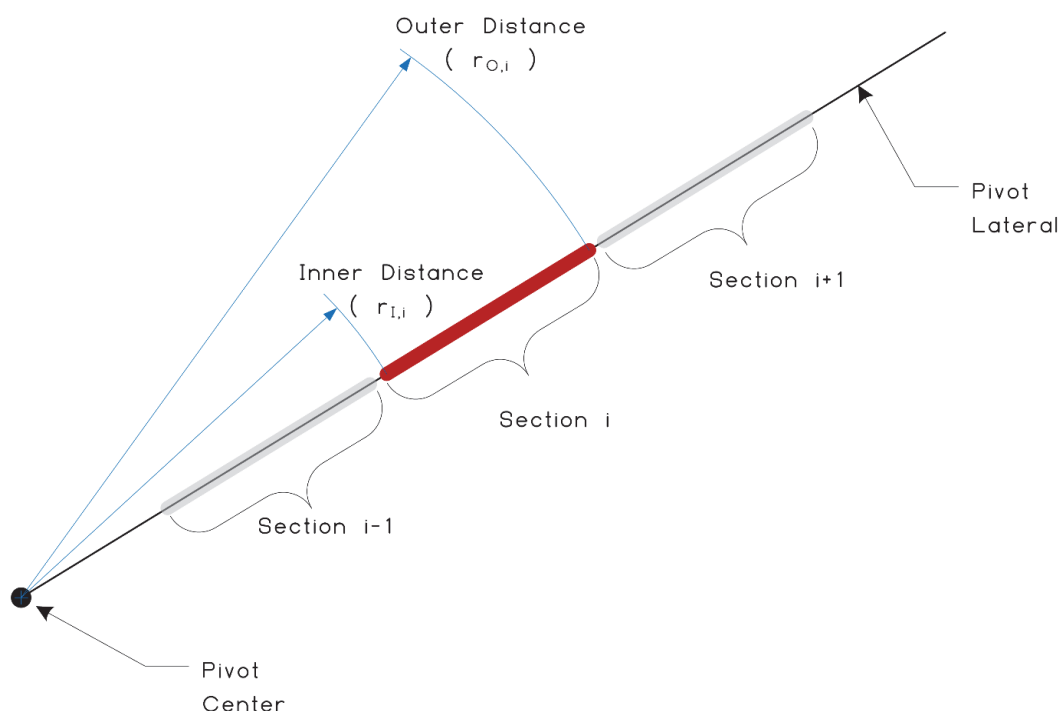


Figure 2 – Schematic illustration of a Section class

The Section concept enables description of the physical and conceptual partitioning of an irrigation system. The physical partitioning applies to the obvious relation of a single section describing a single span of a pivot. The Section class can be used to describe more than a single span. It is entirely valid to have a single Section describe an entire pivot or an individual sprinkler. This flexibility is how Sections, combined with the IrrItem, can document nearly any type of irrigation application. It is important to note, however, that Section definitions are intended to support documenting water applications that differ along the length of the system. Adjacent section definitions that are identical in all respects except position do not enable any additional expository benefit and will increase reporting burden. If a pivot is defined with two sections that both apply the same depth of water each time they are used then the resulting Work Orders, and Work Records will contain unnecessary duplication.

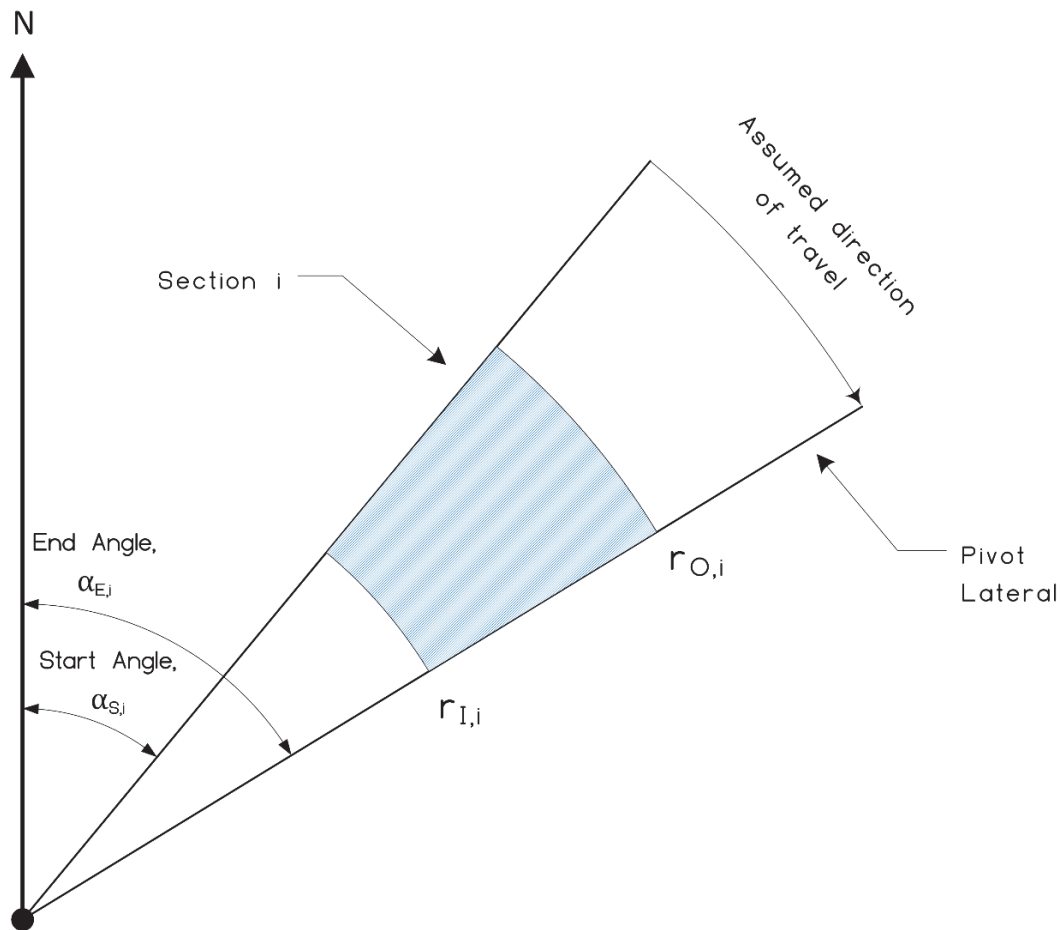


Figure 3 – Schematic view of the area subtended by a Section moving from Start Angle to End Angle

The Section abstraction is not meant as a direct analog of pivot architecture. Instead, the abstraction is convenient for pivots and adequate for any other system type. The Section definitions enable separation of the physical description of the system from the physical description of the system's use. The intent is that future versions of this standard will incorporate a variety of other irrigation system types. Other system types are not disallowed however specific attributes that are unique to particular system types (e.g., hose reel length of a traveling gun or nozzle CV in drip systems) are not included. The intent here is to support pivot systems in a convenient manner but also be flexible enough for most other system types. The Section abstraction will still be relevant for more disparate system geometries because the definition includes an optional geometric specification for the irrigated area.

For non-radial areas, the Section class also includes a SpatialFootprint object that can be used to describe any physical partitioning of the irrigated area. This is achieved using the SpatialScope class defined in Part 1. It is important to note that the radial specification does not, by itself, specify a particular location or area. Figure 3 illustrates how the IrrItem, SectionFlow, and the Section together specify a particular area.

5.2 Description of Irrigation Record

The Section specification, by itself, is not sufficient to document irrigation operations. Standard compliant documents rely on the IrrColl, IrrItem, and SectionFlow classes to complete the documentation requirements. These two classes refer to the Section definitions and enable specification of an amount of water applied at a specific area, at a specific time by a specific subset of the irrigation system. These four facets (how much, when, where, by what) enable precise documentation or specification of water use. These facets are necessary for spatially explicit irrigation systems (i.e., Variable Rate Irrigation) and for accounting of chemigation and fertigation applications.

5.2.1 Irrigation Items and Collections

The IrrItem (Irrigation Item) represents the time-varying physical state of an irrigation system. Properties specified by IrrItem apply to the whole system, and those properties are assumed to be constant over the time interval specified by the IrrItem. A complete irrigation record may contain a list of separate IrrItem objects. Each IrrItem may contain any number of SectionFlow objects described in the following section. Irrigation documents can further organize the IrrItems by grouping them into collections called IrrColl (Irrigation Collection). These collections can also specify some of the time-varying physical properties associated with the irrigation system.

5.2.2 Section Flow

Records of irrigation applications are composed of a collection of objects that describe the shaded areas in Figure 4. These items are called SectionFlow objects and are equivalent to a single application of water over a specific area during a specific window of time. Each SectionFlow object contains a reference to a Section instance. Figure 4 illustrates how each SectionFlow, along with the context from its parent IrrItem, can specify a specific area. By making reference to Sections, the SectionFlow enables compact specification of water application because all of the information that can be “factored out” is contained in the Section definition.

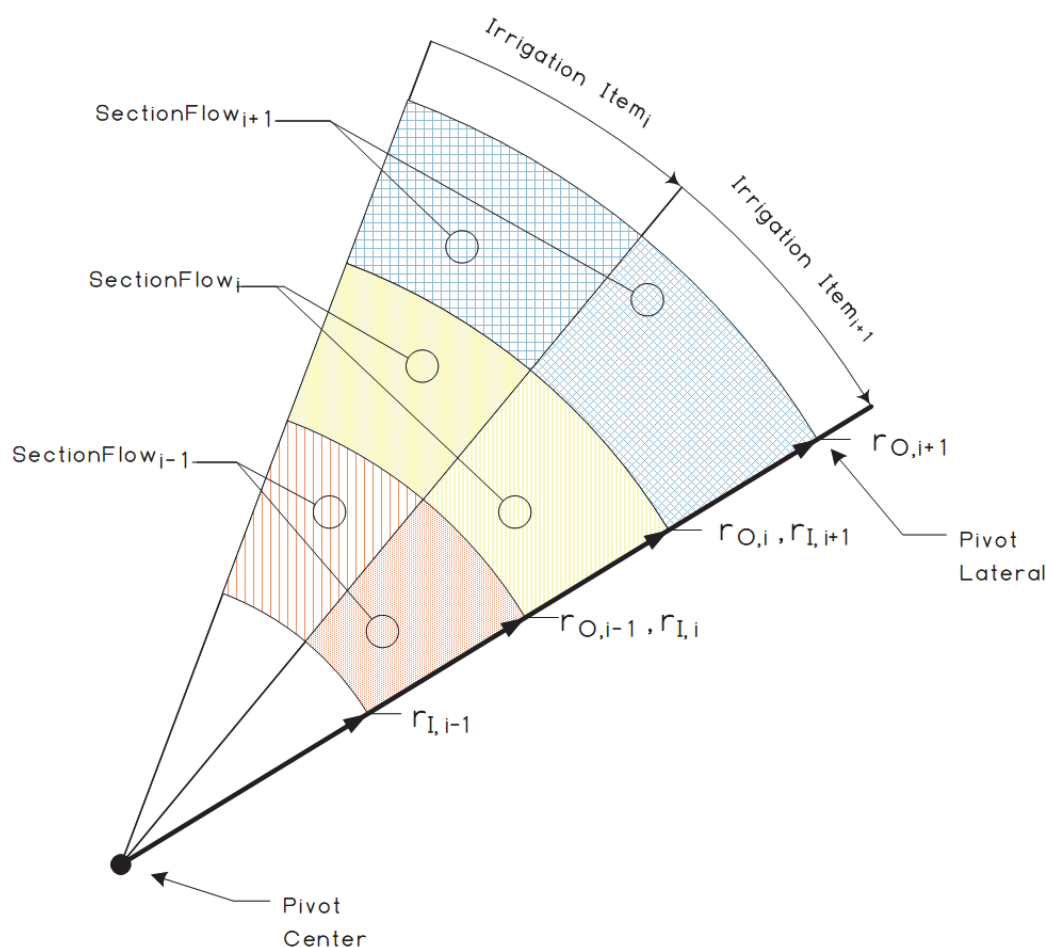


Figure 4 – Six SectionFlow areas associated with three adjacent Section definitions and two adjacent IrrItem.

When applying water with a center pivot irrigation system knowing how much water was applied and where it was applied is essential. With a single section, the area can be calculated by taking the area of the entire circle multiplied by the percentage that was covered as described by the start and end angles. To find the area covered by a specific section use the equation is described below.

$$A_{i,j} = \left(\frac{\alpha_{e,j} - \alpha_{e,i}}{2\pi} \right) (\pi r_{o,i}^2 - \pi r_{l,i}^2) = \left(\frac{\alpha_{e,j} - \alpha_{e,i}}{2} \right) (r_{o,i}^2 - r_{l,i}^2)$$

A SectionFlow describes how water and/or product was applied for section described in the IrrSetup. The water applied is documented as the volume applied and/or in the irrigation depth that was applied over the described area. Either one is required, the other may be calculated by Volume = Depth × Area. Any other substance that is applied with the water is described in the ProductUse class.

5.2.3 Chemigation and Fertigation

Chemigation and Fertigation are handled with a trio of classes whose structure parallels the IrrItem and SectionFlow classes. ProductUse, ProductSummary, and Product classes each document a facet of the overall application of crop nutrition and protection products. These classes are not meant to control or direct operation of chemigation systems. Rather, these are only for documenting the use of a product or specifying the use of a product.

5.2.4 Hierarchical Structure

In the Standard irrigation documents, the SectionFlow, IrrItem, and associated objects appear in a hierarchical structure. The structure is illustrated in Figure 5. In the figure, 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 make reference to objects in parts of other documents. For example, the Section Flow object in the Irrigation Document makes reference to the Section object in the Setup Document. The hierarchy creates parent-child relations such that a child object always appears in the encapsulating context of the parent. Throughout the Standard irrigation records, there is an implicit assumption that the properties of the parent apply equally to all of its children. This enables efficient specification of operating parameters. For example, the IrrColl can specify the irrigation system's pressure. This pressure applies to all of the collection's child IrrItem objects and to all of the child SectionFlow objects. If one of the IrrItems included its own pressure value, that value applies only to that IrrItem and the IrrItem's child SectionFlow objects. The IrrItem's siblings would not need to specify pressure since they inherit this value from their parent IrrColl.

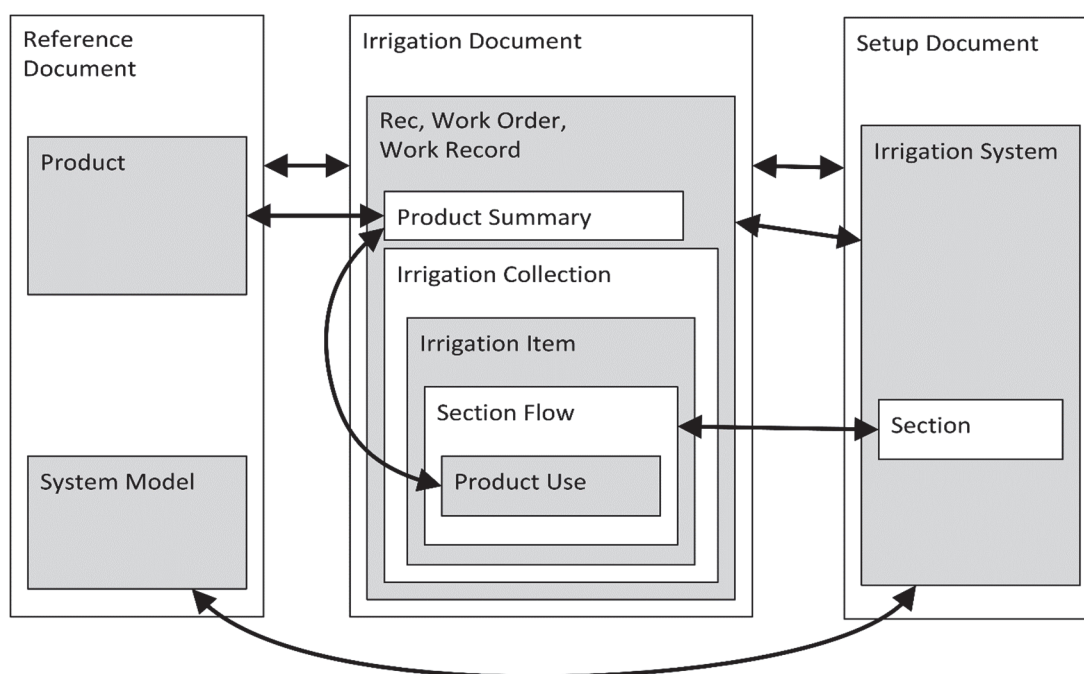


Figure 5 – Relationships among document elements

A single document will typically contain at least one IrrColl, which contains at least one IrrItem, which contains at least one SectionFlow object. 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. Annex A and Annex C contain several examples that illustrate the different permutations and combinations possible with Section, Irrigation Collection, Irrigation Item, and Section Flow.

The same set of abstractions (Irrigation Collections, Irrigation Items, and Section Flow) are used in all documentation of irrigation applications regardless whether the documents describe irrigations that should happen (Recommendations), irrigation that will happen (Work Orders), or irrigation that did happen (Work Records). There are arguably many other ways to represent irrigation records. The Standard uses this particular set of classes to meet three goals. The first is to maintain the efficiency of expression. The hierarchical structure between Irrigation Collections and Irrigation Items, along with the separation of Section definitions from documenting irrigation with Section Flow, both help reduced redundancy in irrigation documents. This efficiency means irrigation documents will be smaller and communication burdens minimized.

Second, the hierarchical structure along with separation of work orders, work records, and recommendations help to document the management process. As will be described in later sections, construction of irrigation documents is meant to reflect the management process. This enables consumers of these documents to differentiate between different management actions even if they result in the same quantity of water applied. The flexibility derived from separating documentation of management from documentation of water enables documentation of a variety of management processes.

Third, the classes and their relationships enable extensibility for future versions of the standard. As stated previously, this scheme is convenient for pivots and linear systems. The hierarchy enables inferring specific areas without explicitly delineating their geometric boundaries. However, in each of the classes where spatial information is relevant, the classes have optional properties for explicit specification of geospatial data. The hierarchical structure can be mapped to virtually any irrigation system and, by using spatially explicit properties, Standard compliant documents can work with any particular geometry. The hierarchical structure assumes that the flow network is tree shaped (branches and nodes). The Standard may not work where the hydraulic system within the field boundary is a recurrent network. Recurrent networks are extremely rare in agricultural irrigation systems, so this limitation was deemed acceptable. The one potential exception is tailwater pump-back in surface irrigation systems.

6 Core Documents for Irrigation Operations

The Operations schema defines three core document types: Reference, Setup, and Irrigation records. These documents follow the core document structure defined in Part 1 of this standard. Some classes defined in Part 1 are only used in Part 3 (this part). This separation is intended to support subsequent versions of the Standard. Those classes defined in Part 1 were deemed general enough that they were likely to see use in other application areas that are not currently part of the standard's scope (e.g., pumping plants or chemigation systems).

Please note that the UML diagrams provided in each of the following sections contain details of class names, property names, types, and multiplicity. Unless otherwise noted, all class properties are optional.

6.1 Core Documents

In much of this standard, exchange of data is described as an exchange of messages or files. These two concepts are used interchangeably throughout the standard. The files themselves contain instances of the classes defined herein. The format of the contents of a message or file depends on the serialization method. The standard generally assumes that the serialization will be either XML or JSON. However, no part of the standard explicitly requires either of these methods. Annex B contains an XML schema that mirrors the object model described in this standard. Annex C contains example XML documents that use the schema defined in Annex B.

6.2 Operations

This is the top-level container for all of the instances of reference, setup, or data records within a particular file (Figure 6). The Operations class has only one property: UoMAuthority. Specification of units of measure is detailed in Part 1. The UoMAuthority applies to all of the child objects of the Operations instance. This constraint

requires that the same units of measure authority be used across the entire file or message. This constraint does produce some inconvenience when assembling documents from multiple sources. For example, when assembling a collection of Work Records and Recommendations derived from different sources, the sources might use different units of measure. In this case, the application assembling the combined document must convert all of the UoM specifications to a single authority. This constraint is intended to reduce the burden on consumers of files by allowing them to assume that the entire document uses the same unit of measure authority.

6.2.1 IrrRefData

This class contains information common to all instances of manufacturers' equipment models and products. This represents data shareable (i.e., non-proprietary) across the whole industry.

6.2.2 IrrSetupData

Grower-specific information used to provide context for data exchange. For example, it is possible for a grower to set up data exchange with a partner such as a crop advisor by sending IrrSetupData.

6.2.3 IrrDocs

This class encapsulates a set of field operations-related documents: recommendations, work orders, and work records.

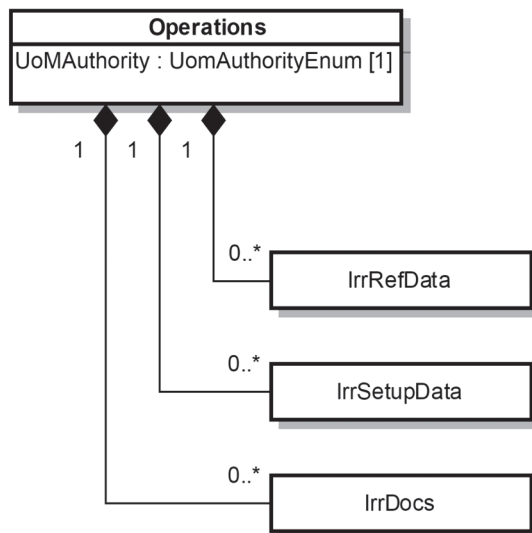


Figure 6 – Operations document general class diagram

6.3 Document Structure

It is generally expected that a single file will contain instances of IrrRefData, IrrSetupData, and IrrDocs. As described in Part 1, maintaining the integrity of irrigation documents requires durable association between the operations data and the setup data associated with those operations. There are some use cases where inclusion of Setup is inefficient, and the child classes of IrrDocs include a mechanism to address that inefficiency. Additionally, there are use cases where an abstract specification of a Recommendation is useful and, in that case, an Irrigation Setup information would not be required. Details can be found in Section 9 and in the implementation guidelines (Section 10).

The document structure follows the same general structure and constraints as defined in S632-1. A particular Operations document may contain any number or combination of IrrRefData, IrrSetupData, or IrrDocs objects. The following sections contain the detailed specification for each of these classes.

7 Reference Data

Reference data contains information common to all instances of Manufacturers' equipment models and products. This represents data shareable across the whole industry and is contained in the class IrrRefData. The UML diagram in Figure 7 shows the classes used in an IrrRefData document. Please note that many of the class properties have the same name as the class name of their type. In the UML diagrams, the type name is appended with the string "Type" so as to differentiate the property name from the type name. The XML schema shown in Annex B uses the same convention. The class descriptions do not use the "Type" appendix for the class names. The following sections provide details on each of the classes and its properties.

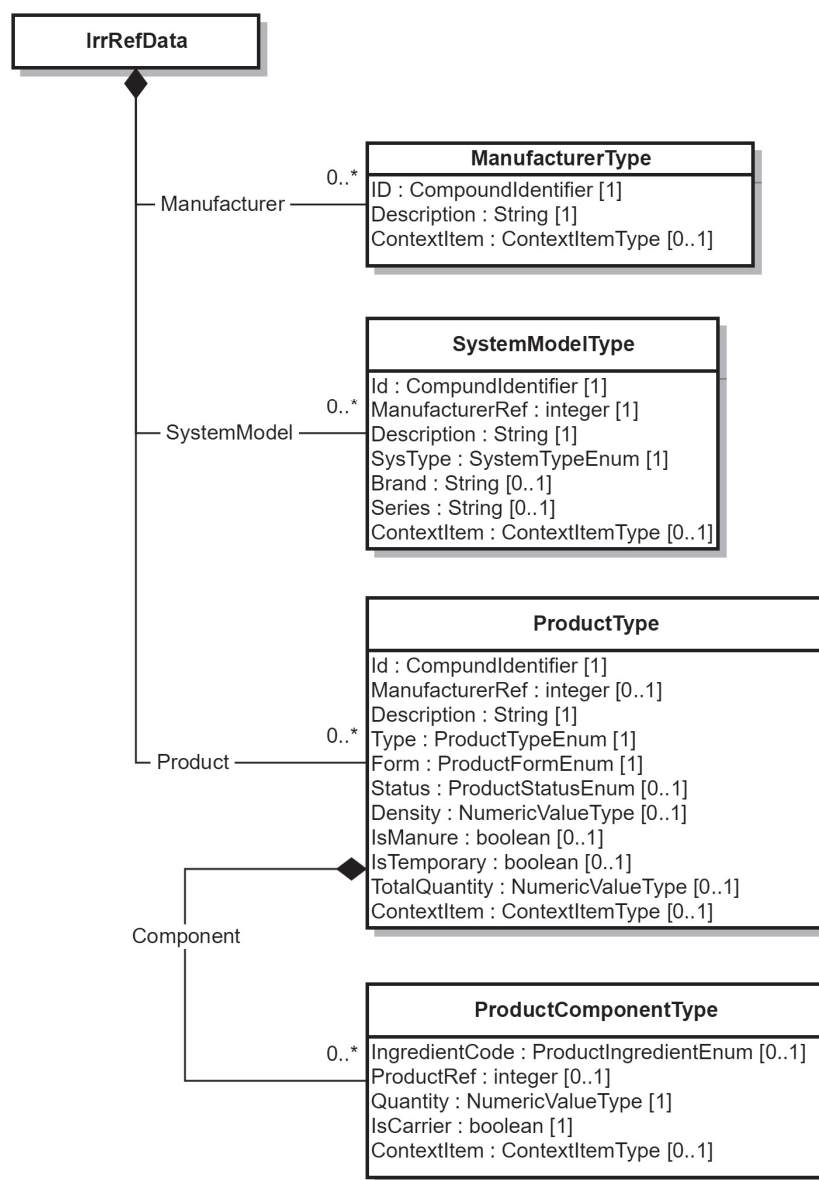


Figure 7 – Operations Reference Data classes

7.1 Manufacturer

The Manufacturer class contains reference data identifying a manufacturer of products or equipment.

Id: CompoundIdentifier for the manufacturer. The manufacturer's GLN can be represented as a ContextItem.

Description: Human-readable manufacturer name.