



**ArcGIS Pipeline Data Model
Version 5.0**

APDM Version 4.0 to 5.0 Change Document

By

**APDM Technical Committee
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1 Purpose and Scope

This document lists the changes to APDM 5.0 from APDM 4.0. The changes in this document represent the work performed by the APDM Standing Committee in conjunction with the PODS ESRI Spatial committee to share best-practices between the two groups in developing a core data model template. The changes also represent user feed-back on APDM 4.0. All changes are documented below and are present in the Full Physical UML model (with example classes), the Core Physical UML model (no example classes) and the Logical Model.

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2 Change Log

Date	Author	Description
20091021	Pcgv	Original draft
20091105	J. Linehan	Revisions and re-organization
20091119-20	Pcgv	Revisions and re-organization <ul style="list-style-type: none"> • Site to Object Class <ul style="list-style-type: none"> ○ SitePoint to offline facility point ○ SiteBoundary to offline nonpoint facility • Remove EventID from ReferenceMode • Changed ParentRefModeEventID to ParentRefMode in Reference Mode • Keep GroupEventID on OnlinePolylineFacility, OnlinePolyline • Remove LineLevel from LineLoop • Remove LineOrder from LineLoop • List clLineFunction attributes with LineFunction attribute • Added PipeJurisdiction to PipeSegment using fcPipeJurisdiction • Updated this document to reflect these changes
20091214	Pcgv	Full Model Changes <ul style="list-style-type: none"> • Relationship class between ClassMetaData/RemovedLine had APDMClass name still in it • Anomaly – corrected spelling on RecommendedRemediation • RemovedLine – generalization arrow was corrupt

		<ul style="list-style-type: none"> • AlignmentSheet – generalization arrow was corrupt • OfflineFeature – Status field length was changed from 0 to 50
20100422	Pcgv/JL	Removed Subtypes from PigStructure, PipeSegment, Tap, Tee, Valve, Marker, Anomaly and InspectionRange and replaced them with domain values where appropriate.
2011	Pcgv	Work in progress completing APDM 5.0 Reference Document

3 Core Model Change Synopsis

This list details the changes to the core model. The section is provided as a quick reference for APDM users who want to migrate their databases quickly to APDM 5.0.

- Convert all domains to esriFieldTypeString
- Add clRefMode domain
- moved PipeFunction attribute from PipeSegment to Lineloop as LineFunction
- moved LineType attribute from LineLoop to PipeSegment as PipeJurisdiction
- added LineJurisdiction to LineLoop w/ clLineJurisdiction domain (Offshore, Onshore)
- Convert EventID to esriTypeGUID, add GlobalID as esriTypeGlobalID
- Long Integer Precision set to 9
- Added AuditObject Abstract Class
- Moved specification field from Fitting to relevant concrete classes
- Removed LineLevel and LineOrder attribute from Lineloop
- Added XYZ coordinates to point feature abstract classes
- Add RouteEventID to all online point/polyline features
 - Add Measure and Begin/End Measure values for online point/polyline features
 - Created relationships for ROUTE from online features to station series
- Removed AltRefMeasure object class and relationships from Online Features
 - All relationships touching AltRefMeasure need to be corrected
- Remove GroupEventID Field from CenterlinePoint, CenterlineObject abstract classes
- Delete StationSeries and ControlPoint subtypes
- Rename APDMClass to ClassMetaData
- Redefined ReferenceMode table
- Merged ControlPoints from different reference modes into single set of ControlPoint features
- Site is object class (CenterlineObject) with related SitePoint and SitePolygon feature classes
- Dropped between ReferenceMode and ControlPoint
- Updated relationships between ReferenceMode and ClassMetaData (formerly APDMClass)
- Updated relationships between ReferenceMode and StationSeries
- Relationship betw relationship een LineLoop and OwnerOperator is 1-M instead of a M-N.
- Where possible removed subtypes and converted subtype values to domains.

4 Domains

4.1 Changes to the Core Model

4.1.1 Convert string domains to String Coded Value domains

- **Change** - Use a string coded value domain as the default in the APDM. Where applicable set all coded value domain fields to type String with a Length of 50 characters. The standard default values for all coded value domains will remain “Unknown” and “Unknown-Verified”
- **Reasoning** - Defining all coded domain values as string types allow the end-user to see the coded value and the description for a domain field as the same value instead of seeing a ‘numeric’ representation of the description. This allows for better visual recognition of the data using industry standard tools such as SQL and the continued use of domain values for data integrity purposes. Another benefit is that string value fields allow existing database implementations to continue to use numeric values to maintain compatibility with existing enterprise systems. To date research shows that string type coded value domain fields do not affect database performance where the length of the fields remains less than 90 characters in length.

4.1.2 Added clRefMode domain

- Included just Continuous and Engineering values in this domain (Core only, all other values added for Full)
- Set default value of RefMode field in StationSeries to ‘Continuous’
- Removed relationships to ReferenceMode
- Removed relationship to APDMClass (now MetaDataClass)

4.1.3 Rename Domains - Move PipeFunction to LineFunction

- fcPipeFunction to clLineFunction as LineFunction
 - Blowoff
 - Bypass
 - Crossover
 - Design Phase – No Pipe
 - Header (Trunk)
 - Interconnect
 - Lateral
 - Launcher
 - Kicker
 - Mainline
 - Receiver
 - Storage Line
 - Tap Line
 - Well Line
- clLineServiceType to fcPipeJurisdiction as PipeJurisdiction
 - Distribution
 - High Pressure Gathering
 - Low Pressure Gathering
 - Transmission

- Added `clLineJurisdiction` to `Lineloop` as `LineJurisdiction`
 - Offshore
 - Onshore

4.2 Changes to the Full Model

4.2.1 Change domain `fcNotApplicable` default value.

- **Change** - `fcNotApplicable` default value to 0 rather than -1 which it currently is.
- **Reasoning** - The `PipeJoinMethod` feature class has an attribute called `Manufacturer` that uses the `fcNotApplicable` coded value domain. This feature class has a `SubType` field. The different subtype classes each use different domains for the `Manufacturer` field. The default value for this field is 0. The `fcNotApplicable` coded value domain does not have a default value of 0. Setting the `manufacturer` field to a value of 0 for a subtyped feature having the `fcNotApplicable` domain will cause ArcMap to crash.

5 Changes to Abstract Classes and and Meta Data Tables

5.1 Changes to the Core Model

5.1.1 Converted `EventID` to `esriTypeGUID`. Added `GlobalID` field as `GlobalID`.

- **Change** - Replace the existing data type for the `EventID` field in all classes from (String type, 38 length) to the ESRI GUID field type. This change would be applied to the `APDMObject` and `FeatureArchive` Abstract Classes.
 - Replace all existing `EventID` style foreign keys that are defined with the (String, 38 length) data type to the new ESRI GUID data type
- **Reasoning** - ESRI is supplying two new data types for defining attributes with ArcGIS 9.2. `GlobalID` is a unique GUID identifier field. The `GlobalID` field is maintained by the underlying ArcSDE engine and is used to uniquely identify features and objects in a geodatabase regardless of what class those features belong to. ESRI maintains the population of values in any field defined by this data type. The values in field are automatically populated when new features and objects are added to a geodatabase. Using this field would remove one of the largest hurdles facing new users implementing APDM – how to populate the `EventID` field with GUID values. Only one field within a given class can be defined with this data type. A `GlobalID` field is required if ArcGIS Replication is to be implemented against a Geodatabase. The `GlobalID` field type represents all the functionality and parameterizations that have been stipulated for the existing `EventID` field. It is recommended that the `EventID` field data type be switched. The GUID data type is a predefined GUID style data type that is easier to maintain from the UML level and fully supports the creation of GUID values including validation that the GUID values are properly formatted. Support of these two field data types are congruent with ESRI's current technology offering.

5.1.2 Long Integer Precision has been set to 9.

- **Change** - Reset all Long Integer precisions in the APDM UML to 9
- **Reasoning** - Different RDBMS solutions (Oracle, MS SQL Server) allow different Long Integer precisions values. Each RDBMS maintains it's own definition of a Long Integer data type with some setting the precision at 10 digits and others at 9 digits. Currently ArcCatalog does not recognize or support anything defined in a UML document with a precision greater than 9 digits. Ultimately when a geodatabase is created using the Case Tool Wizard in ArcCatalog the underlying RDMBS will set the precision of the Long Integer and Double values regardless of what is specified in the UML. Removing

the precision stipulation in the documentation will reduce documentation maintenance work. Remove the Long Integer/Double precision/scale notation from the APDM White Paper.

5.1.3 Create an Activity Extension Abstract Class – (added as child of Non-Facility Object)

- **Change** - Create an Activity Extension Abstract Class that provides an extension to the Activity Object Class in the event that specific types of activities require more attributes to define a particular activity. The Activity Extension abstract class will have a 0..1 relationship with the Activity Object Class. Classes inheriting from this abstract class will promulgate the relationship and add additional attributes to define the particular activity in more detail.
- **Reasoning** - (Logical) Requires a 0..1 relationship with the Activity Object Class (this is not present in UML). An activity in the APDM is defined as something that an operator does to a pipeline during the normal course of planning, operating, inspecting, maintaining, repairing, managing, and reporting on a pipeline system. Activities in APDM are left purposefully vague so that they may be implemented as needed by an operator that suits one or more particular business purposes. Activities are also used in APDM to track history, comments and integrate features in separate classes together as unified groups. Some activities (such as ILI inspections, HCA analysis) require additional attributes to describe the activity.

5.1.4 Created AuditObject Abstract Class containing:

- ActivityEventID
- ActivityDate
- (Logical) <ParentClass>EventID (and 1..m wormhole from Parent Class to Audit Class)
- (Logical) (Optional 0..1 optional relationship from Activity to class inheriting from AuditObject)
- (Logical) M-N wormhole to ExternalDocument

5.1.5 Segregated Specification Field for Fittings

- **Change** - Remove the Specification Field from the APDMFitting Abstract Class

5.1.6 Added XYZ Coordinate Attributes

- **Change** - Added POINT_X, POINT_Y, POINT_Z attributes to OnlinePoint, OnlinePointFacility, OfflinePoint, OfflinePointFacility and ControlPoint
 - Set Precision/Scale for these fields to 15, 8 for X and Y
 - Scale of 8 is designed to handle Latitude/Longitude coordinates gathered from GPS systems.
 - Set Precision/Scale for Z to 15, 2
- **Reasoning** - As existing APDM implementations move to a more event-based paradigm having access to the XYZ coordinates for point features at the attribute level allow display of these events using ArcGIS desktop and field data collection style tools without the need for showing the underlying pipeline centerline station series. Coordinate attributes can also be queried using SQL if needed.
 - Adding coordinate values adds an alternate behavior for online features. The feature's location provenance will be Route and Measure or Coordinate information. The typical approach for locating an online feature is to find the measured position along a route and then derive the coordinate values. If this process is reversed then the coordinate values could be assigned and assuming that the derived location of the feature corresponds to an online location then the measure position can be derived.
 - Null values are used as default. Using 0.00 values create false data.

5.1.7 Add Alternate Reference Mode station values

- **Change** - Add Alternate Reference Mode station values to Online feature classes.
 - Added or changed fields to abstract classes inheriting from OnlineFeature abstract class
 - Added Measure field
 - Changed FK field root name from StationSeriesEventID to SeriesEventID in Online classes
 - Added RouteEventID to Online classes
 - Added or changed fields to in CenterlinePoint abstract class (affects ControlPoint)
 - Added MeasureValue field (dropped from ControlPoint)
 - Added StationValue field (dropped from ControlPoint)
 - Changed FK field root name from StationSeriesEventID to SeriesEventID in Online classes
 - Added RouteEventID to Online classes
 - Changed relationship name from StationSeriesControlPoint to SeriesControlPoint
 - Added 1..M relationship from StationSeries to ControlPoint as RouteControlPoint (RouteEventID to EventID)
 - Added to CenterlinePolyline abstract class:
 - BeginMeasure (moved from StationSeries concrete class)
 - EndMeasure (moved from StationSeries concrete class)
 - BeginSeriesEventID (moved from StationSeries concrete class)
 - EndSeriesEventID (moved from StationSeries concrete class)
 - Added fields to StationSeries Concrete Class
 - Added ParentStationSeriesEventID field (This field serves as a self-relate FK from the StationSeries featureclass to itself. Currently ESRI does not support self-relates in the Geodatabase).
 - Kept the following names consistent with APDM 4.0
 - ParentStationSeriesEventID
 - FromStationSeriesEventID
 - ToStationSeriesEventID
 - StationSeriesName
- **Reasoning** - This option has been suggested as part of the PODS Spatial working group and represents an extension to the existing APDM design rather than alteration of what is there. Adding alternate reference mode station values to online feature classes would improve performance by reducing the need to traverse relationship classes from online feature classes to the AltRefMeasure object class. All stationing values would be present in the online feature classes for easy reference, comparison and updating. Three fields would be added to the ReferenceMode APDM Metadata class to denote the field names for each reference mode – one field for point features, two fields (representing begin/end station values) for polyline features.

5.1.8 Deleted the AltRefMeasure object class

- **Change** – The following were deleted:
 - Deleted M-N relationship between AltRefMeasure and SubsystemRange (Core only)
 - Deleted relationships between all Online classes and AltRefMeasure (Full only)
 - Deleted the SubType binary associations between AltRefMeasure and Reference Mode subtypes.
- **Reasoning** – Adding alternate reference mode station values to online concrete classes rendered the AltRefMeasure object class obsolete.

5.1.9 Removed GroupEventID field from Abstract Classes

- **Change** - Remove GroupEventID Field from CenterlinePoint, CenterlineObject classes
- **Reasoning** – GroupEventID was also intended to relate continuous measure control points to engineering stationing control points. Implementing. Merging control points into single features removes the need for a grouping attribute. GroupEventID is continued in OnlinePolylineEvents and OnlinePolylineFacility events since a PRM could be interrupted and therefore a mechanism for relating like attributed online polyline events is required.

5.1.10 Deleted StationSeries and ControlPoint Subtypes (Core and Full)

- **Change** – Remove subtypes:
 - Remove RefMode from ControlPoint
 - Remove SubTypes from ControlPoint
 - Remove SubTypes from StationSeries.
- **Reasoning** – Alternate reference modes are now stored with each concrete class rendering these SubTypes obsolete.

5.1.11 Renamed APDMClass table to ClassMetaData.

- **Change** –
 - Renamed APDMClassType attribute to ClassType.
 - Renamed gnAPDMClassType domain to gnClassType.
 - Renamed relationships from ClassMetaData to CPLocation, RemovedPoint, RemovedLine, (Full Model Only)
 - Renamed relationships from ClassMetaData to OnlineLocationClass from APDMClass<Target_Class_Name> to <Target_Class_Name>ClassID. (Full Model Only)
 - PODS Spatial added additional attributes to APDMClass (ClassMetaData)
- **Reasoning** – Removed ‘APDM’ nomenclature from model to match PODS Spatial.

5.1.12 Moved META Classes (Full and Core) to EventSupport Static Structure Diagram

- They still appear in the Abstract Class section of the Logical Model Poster.
 - ReferenceMode,
 - APDMClass,
 - OnlineLocationClass
- PODS Spatial Notes:
 - PODS Spatial uses DateInstalled rather than InstallationDate in FacilityObject, OfflineFacility, OnlineFacility Abstract Classes
 - PODS Spatial uses Description rather than Remarks in FeatureArchive Abstract Class
 - PODS Spatial adds SourceGCL to FeatureArchive Abstract Class
 - PODS Spatial renames OfflineFeature Abstract Class to OfflineFeature_AC. PODS already has a OfflineFeature table.

5.1.13 Rebuilt Reference Mode Table

- **Change** – Rebuilt ReferenceMode table to support both continuous measure and engineering stationing.

- Reasoning** – The ReferenceMode table contains information about the method of measure used in locating features. The ReferenceMode may be in Continuous, Engineering, MilePost etc.

Class Name:	ReferenceMode
Feature Class Geometry:	Implemented as a standard ESRI Object Class
Feature Dataset:	--
APDM Class Type:	ESRI Object → ReferenceMode
Attributes: <small>(name, type, length, precision, scale, domained, notes)</small>	<p>RefMode (String) – clRefMode (Default: Unknown) – Describes the type or name assigned to the reference mode such as Continuous, Engineering, Mile Point etc.</p> <p>RefModeMeasureRootName – (String, 50) – the name that is applied to measure and station fields for each form of measurement in Online classes. For example, the reference models Continuous and Engineering will use the values Measure and Station for this attribute respectively. Thus Online points will have the Measure and Station fields and OnlinePolylines will have BeginMeasure, EndMeasure, and BeginStation and EndStation fields.</p> <p>RefModeBasis (Long Integer, 9) – gnRefModeBasis (Default 0=Unknown) – Describes the basis from which station values are specified or derived for a given reference mode.</p> <p>RefModeType (Long Integer, 9) – gnRefModeType (Default 1=Uninterrupted and Adjustable) – Describes the behavior of the centerline stationing when a reroute is performed on a LineLoop. Also defines if station equations can exist for a given reference mode.</p> <p>RefModeUnits (Long Integer, 9) – gnRefModeUnits (Default 0=esriUnknownUnits) – describes the units that the stationing values for a reference mode represent.</p> <p>IsPRM – (String) – gnYesNo (Default = Unknown). A Yes value indicates that this is the primary or master referencing mode used to locate features on the centerline.</p> <p>ParentRefMode – (String) – clRefMode – Self Relate field indicating reference modes are considered to be parent modes to which child reference modes are related to or derived from. This field will be NULL for parent reference modes and populated with the parent reference mode value for rows describing child reference modes. The Engineering reference mode will have the ‘Continuous’ value of the Continuous reference mode in this field.</p> <p>RefModeRootName – (String, 50) - This is the root name for FK fields in Online feature classes pointing to the station series feature class. The values End and Begin will be appended to these ‘root’ values to create the full FK field names from Online classes to StationSeries. For example: If RouteEventID is the value in this attribute then the attribute in a OnlinePolyline feature class will be BeginRouteEventID and EndRouteEventID.</p>
Relationships: <small>(cardinality, optionality, composite, inheritance)</small>	<p>ReferenceModeControlPoint (core): ReferenceMode is 1:M with ControlPoint.</p> <p>ReferenceModeStationSeries (core): ReferenceMode is 1:M with StationSeries.</p>
SubTypes:	--

Reference Mode Sample Data

RefMode <d>	RefModeRootName	RefModeMeasureRootName	RefModeUnits	RefModeType <d>	RefModeBasis <d>	IsPRM	ParentRefMode <d>
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	(root for FK)	<d>				
Continuous	Route Measure	Feet	Uninterrupted and Adjustable	3D Geoid	Yes	<NULL>
Engineering	Series Station	Feet	Interrupted and Not Adjustable	3D Geoid	No	Continuous

5.2 Changes to the Full Model

5.2.1 Segregated Specification Field for Fittings

- **Change** - Add the Specification Field in the PipeSegment, Valve, Meter, Elbow, Tee, Reducer, Closure and Flange
 - i. Renamed fcSpecification to fcSpecificationPipe
 - ii. Added Specification field to Valve, Meter, Elbow, Tee, Reducer, Closure
 - iii. Added the following domains to handle specifications for the above-listed classes:
 1. fcSpecificationMeter
 2. fcSpecificationElbow
 3. fcSpecificationTee
 4. fcSpecificationReducer
 5. fcSpecificationClosure
 6. fcSpecificationValve
- **Reasoning** - Any feature class or event-based object class that inherits from the APDMFitting Abstract Class will inherit the Specification attribute AND the assigned coded value domain to that attribute. The valid value list of specifications that describe features such as valves and flanges are completely different from each other and, from a database integrity and normalization stand-point, having a single domain containing specification values for both of these feature types would cause data integrity issues as a user may describe a valve with a flange specification. Abstract Classes are supposed to be the lowest and most generic representation of a super class. The specification field is unique to the feature type it is describing and thus must be placed in the concrete classes. Field is deleted from the Core Model but remains in the concrete classes in the full model.

5.2.2 Updates for AltRefMeasure to Full Model (See 3.2.1.7)

- The following Online concrete classes were modified in the Full model:
 - Casing, Coating, CouldAffectSegment, DOTClass, HCARange, HCASegment, InspectionRange, LineCrossingEasement, OperatingPressure, PipeSegment, PressureTest, RightOfWay, RiskAnalysis, Sleeve, SubSystemRange, Anomaly, AnomalyCluster, Appurtenance, Closure, CPLocation, Elbow, ElevationPoint, FieldNoteLocation, Instrument, Leak, LineCrossingLocation, MarkerLocation, Meter, PipeJoinMethod, Reducer, StructureLocation, Tap, Tee, Valve, Vessel
 - Renamed StationSeriesEventID to RouteEventID
 - Added SeriesEventID (FK) field

6 Concrete Class Modifications

6.1 Changes to the Core Model

6.1.1 Merged Control Points

- **Change** - Stop maintaining multiple sets of control points for each reference mode.
 - Only duplicate control points are stored at equation points.
- **Reasoning** – A control point is a known point of XYZ and M location. There is no reason to not store multiple M values in the control point feature class. Now the ControlPoint feature class can contain multiple foreign key fields to multiple station series records. See the Merged Control Points section of this document (below) for more information.

6.1.2 Renamed PipeFunction to LineFunction

- **Change** – Redefine the type and function of a pipe to be more indicative of the line.
 - Move PipeFunction Attribute to the LineLoop Object Class as LineFunction
 - Moved LineType Attribute to the PipeSegment feature class
 - Added LineJurisdiction (clLineJurisdiction) to LineLoop Object Class.
 - See Issue [5.1.3](#)
- **Reasoning** - The PipeFunction attribute describes the function of a line (mainline, interconnect, branch) rather than that of an individual pipe segment (which is defined as a stick or by Heat number). In APDM lines represent a set of continuous pipe, typically of the same outside diameter, that serves one function within the pipeline. APDM is designed to allow operators to describe functionality of a line at the lineloop level and to break the pipeline system into lines based on this functionality. It is conceivable that an APDM implementation will not have a PipeSegment feature class especially for international operators with assets in many countries where the use of APDM is limited to presenting an overview of Pipeline locations rather than detailed pipeline attributes. The LineLoop Object class is a part of the APDM core and is therefore required. Another consideration is that future integration between ESRI data models would require detailed description and definition of pipelines at the line level to differentiate between transmission, distribution, high and low pressure gathering pipelines. LineJurisdiction was added to differentiate between onshore and offshore pipelines.

6.1.3 Turn Site into an Object Class

- **Change** – Site from a point feature class to a Object Class. Inherits from CenterlineObject.
- **Reasoning** – A single site can have multiple forms of geometric representation. Usually it is just a single point (attached to the network) and one or more polygons.
 - i. SiteName and SiteType attributes belong to Site

6.1.4 Keep SitePoint and add SiteBoundary

- **Change** – Keep SitePoint as a offline point facility feature class.
 - Keep SiteBoundary as a offline NonPoint facility feature class.
- **Reasoning** - Sites can be represented as point features, some also have polygonal boundaries. It is common to have more than one polygon representing a site boundary.

6.2 Changes to the Full Model

6.2.1 PipeSegment

- **Change** – Moved LineType from LineLoop – domain cLineType becomes fcPipeJurisdiction
- **Reasoning** – Whether a pipe is a transmission, gathering, distribution is completely subjective and applies to the pipe rather than the line. The same line can contain high pressure distribution that is not classified as transmission or low pressure distribution. This is a pipe attribute, not a line attribute and it changes a lot.

6.2.2 Valve Information

- **Change** - Added new fields to Valve with domains as appropriate:
 - Material with fcValveMaterial
 - Added Walworth, M&J, Daniel, Foster values to fcValveManufacturer domain.
 - ResponseTime (Integer) attribute (Represents the shut-off time for a valve. Added to support emergency flow restriction device analysis)
 - NominalPressure attribute to Valve feature class. – added as integer field
- **Reasoning** - The current set of attributes describing the example valve class do not present a complete view of a valve feature

6.2.3 Added OnlineFieldNote

- **Change** - Break up FieldNote to OnlineFieldNote and OfflineFieldNote
 - Replicate FieldNote and rename to OnlineFieldNote
 - Associate OnlineFieldNote as OnlinePoint Abstract Class
- **Reasoning** - More operators are conducting field surveys and bringing back field notes. New pipeline is being built that requires various surveys. Experience is showing that field notes comprise two different types – online and offline. Online field notes typically refer to the beginning and ending of polygon type events that are intersected by the centerline and single occurrences – aka a crossing. Offline field notes refer to locations of features off the centerline like structures. Both sets of data should contain XY and Station location.

6.2.4 Modification to StructureOrIDSite (Existing, Modifications made to Full model only)

- **Change** - Added the following attributes:
 - IdentifiedSite (gnYesNo)
 - IdentifiedSiteType with enIdentifiedSiteType domain
 - SiteDescription
 - Added the following relationships
 - i. StructureOrIDSiteDOTClassSgtMN: StructureOrIDSite is M:N with DOTClassSegment
 - ii. StructureOrIDSiteDOTClassSgt1M: StructureOrIDSite is 1:M with DOTClassSegment
- **Reasoning** – Clarification of Structures or Sites used in HCA determination.

6.2.5 Modifications to DOTClass (Existing Class, Full Model Only)

- **Change** – Added new attributes:
 - ActivityEventID – M..1 FK relationship field from DOTClass to Activity
 - CorridorTolerance (Double, 15,2)

- IDSiteBufferRadius (Double, 15,2)
- ClusterBufferEventID (String, 38) – M..1 FK relationship from DOTClass to ClusterBuffer
- Added new relationships:
 - i. ActivityDOTClass: DOTClass is M:1 with Activity
 - ii. ClusterBufferDOTClass: DOTClass is 1:1 with ClusterBuffer
- **Reasoning** – Clarification of DOTClass clustering.

6.2.6 Modifications to HCARange (Existing Class, Full Model Only)

- **Change** – Added the following attributes:
 - ActivityEventID - M..1 FK relationship field from HCARange to Activity
 - Added the following relationship:
 - ActivityHCARange: HCARange is M:1 with Activity
- **Reasoning** – Clarification of HCARange activity

6.2.7 Modifications to HCASegment (Existing Class, Full Model Only)

- **Change** – Added new attributes:
 - ActivityEventID - M..1 FK relationship field from HCASegment to Activity
 - PIRFactor (Double, 15,2)
 - Provenance (String, 50) - opHCAMethod1Provenance (new domain)
 - HCAMethod (Integer, 9) <Subtype Field>
 - SubTypes:
 - 1 – Method 1
 - 2 – Method 2
 - Added new relationship:
 - ActivityHCASegment: HCASegment is M:1 with ActivityMerged
- **Reasoning** – Clarification of HCASegment methods and activity.

7 Relationship Modifications

7.1 Changes to the Core Model

7.1.1 Dropped relationship between ReferenceMode and ControlPoint

- There is no RefMode field in control point.
- There is no need for a relationship. Control points are reference mode agnostic.

7.1.2 Relationships between ReferenceMode and StationSeries

- Repaired relationships between ReferenceMode and StationSeries using RefMode attribute as PK-FK key rather than SubTypeCD.

7.1.3 Change in LineLoop/OwnerOperator relationship.

- **Change** – Change OwnerOperator / LineLoop association from M:N to 1:M
- **Reasoning** - This relationship has always been a M:N from OwnerOperator to LineLoop. It really needs to be a 1-M from LineLoop to OwnerOperator.
 - OwnerOperator acts as the intersection table between Company and LineLoop.

- OwnerOperator has all the meta data required to accurately describe the company, role, percentage and lineloop.

7.2 Changes to the Full Model

7.2.1 Fixed and added relationship classes:

- ElevationPoint M-1 to StationSeries (Non-Core)
- MarkerLocation M-1 to StationSeries (Non-Core)
- FieldNoteLocation M-1 to StationSeries (Non-Core)

8 New Concrete Classes (Full Model Only)

8.1 Changes to the Core Model

No changes since Full Model is an example implementation of the Core features.

8.2 Changes to the Full Model

8.2.1 Well Concrete Class

- **Change** - Add a Well class to support Gathering pipeline systems. (Full model)
- **Reasoning** - There is an industry effort to integration the energy and APDM models in conjunction with developing a gathering system model in the short term adding a well feature to model helps the gathering folks out a little.

Class Name:	Well
Feature Class	Implemented as a Z-Aware Point feature class.
Geometry:	
APDM	ESRI Object → Feature → FeatureArchive → OfflineFacility → OfflinePointFacility
Inheritance:	
Attributes: (name, type, length, precision, scale, domain, description)	APINumber (String) – Assigned well number. Additional identifier that is commonly used in the field. GeologicalFormation (String) – Description of the geologic formation that the well is tapping into. LegalDescription (String) – NE of Section Five. Operator (FK, GUID) – SeasonallyActive (gnYesNo) – Default Unknown – Does the well shut down for part of the year. TiedInDate (Date) – Date the pipeline company connects the well. WellName (String) – Additional identifier. WellType (fcWellType) – Default Unknown
Relationships: (cardinality, optionality, attributes, composite)	Contact: Well is M:1 with Activity. Site: Well is M:1 with Site.
SubTypes:	--

8.2.2 ClusterBuffer Concrete Class

- **Change** – Add a ClusterBuffer class to support DOTClass clustering (Full Model).
- **Reasoning** – Contains information supporting DOT Class determination using clustering.

Class Name:	ClusterBuffer
Feature Class	Implemented as a Z-Aware Polygon feature class.
Geometry:	
APDM	ESRI Object → Feature → Feature Archive → OfflineFeature
Inheritance:	
Attributes: (name, type,	ActivityEventID (String, 38) – Foreign key to an Activity object record. BufferRadius (Double, 15,2) – The radius of the clustering buffer (by definition, 220

length, precision, scale, domain, description)	yards). BufferTolerance (Double, 15,2) – A tolerance applied to the cluster buffer to account for any spatial uncertainties in the location of the centerline or surrounding structures.
Relationships: (cardinality, optionality, attributes, composite)	ActivityClusterBuffer: ClusterBuffer is M:1 with Activity ClusterBufferDOTClass: ClusterBuffer is 1:1 with DOTClass ClusterBufferDOTClassSgmnt: ClusterBuffer is 1:M with DOTClassSegment
SubTypes:	--

8.2.3 DOTClassCorridor Concrete Class

- **Change** – Add DOTClassCorridor class to support DOT Class analysis (Full Model).
- **Reasoning** – The DOTClassCorridor holds the buffer polygon used in determining DOT Class for the line loop.

Class Name:	DOTClassCorridor
Feature Class Geometry:	Implemented as a Z-Aware Polygon feature class.
APDM Inheritance:	ESRI Object → Feature → Feature Archive → OfflineFeature
Attributes: (name, type, length, precision, scale, domain, description)	ActivityEventID (String, 38) – Foreign key to an Activity object record. CorridorRadius (Double, 15,2) – The <i>radius</i> of the DOT Class corridor (for the class corridor itself, by definition, 220 yards; for the identified site corridor (qualifying structures or outside areas of public assembly), by definition, 100 yards). Do not confuse this field with the CorridorWidth field found in DOTClass. CorridorTolerance (Double, 15,2) – A tolerance applied to the corridor to account for any spatial uncertainties in the location of the centerline or surrounding structures. DOTCorridorType (String, 50) opDOTClassCorridorType – the type of class corridor (Class Location, Identified Site).
Relationships: (cardinality, optionality, attributes, composite)	ActivityDOTClassCorridor: DOTClassCorridor is M:1 with Activity
SubTypes:	--

8.2.4 DOTClassSegment Concrete Class.

- **Change** – Add DOTClassSegment class to support DOT Class analysis (Full Model).
- **Reasoning** – The DOTClassSegment is a polyline representation of the lineloop dynamically segmented to specific DOT classes.

Class Name:	DOTClassSegment
Feature Class Geometry:	Implemented as an M-Aware Polyline feature class.
APDM Inheritance:	ESRI Object → Feature → Feature Archive → OnlineFeature → OnlinePolyline

<p>Attributes: (name, type, length, precision, scale, domain, description)</p>	<p>ActivityEventID (String, 38) – Foreign key to an Activity object record. BIHOStructureCount (Integer, 9) – The number of BIHO’s contributing to the segment. MultiUnitResidential (String, 50) gnYesNo – A yes/no flag field indicating whether multi-unit residential structures contribute to this segment. IdentifiedSite (String, 50) gnYesNo – A yes/no flag field indicating whether an indentified site(s) contribute to this segment. ClusterDowngrade (String, 50) gnYesNo – A yes/no flag field indicating whether the segment class value has been downgraded due to clustering. ClassLength (Double, 15,2) – The 2D/3D length of the class segment (in feet). UnclusteredClassType (String, 50) opDOTClassType – The raw class designation prior to clustering (Class I, Class II, Class III, Class IV). ClusteredClassType (String, 50) opDOTClassType – The final class designation post clustering (Class I, Class II, Class III, Class IV). Provenance (String, 50) opDOTClassProvenance – A lookup value summarizing all of the factors contributing to the class designation of the segment (e.g. 10<BIHO<46, 10<BIHO<46 w/IDSite(s), BIHO>46, etc.). ClassSource (String, 50) opDOTClassSource – The methodology used to derive/assign the class type to the class segment (Calculated, Manual). CorridorWidth (Double, 15,2) – The width of the corridor surrounding the class (by definition, 440 yards). CorridorTolerance (Double, 15,2) – A buffer tolerance applied to the class corridor to account for any spatial uncertainties in the location of the centerline or surrounding structures and/or identified sites. IDSiteBufferRadius (Double, 15,2) – The search radius around the pipeline for class analysis for identified sites (qualified structures or outside areas of public assembly as defined in CFR 49 § 192.5) (by definition, 100 yards). DateCalculated (Date) – The date the class value was determined and assigned to the class segment. DOTClassEventID (String, 38) – Foreign key relationship to a DOTClass feature that aggregates this and related DOTClassSegment features by class value. StructureOrIDSiteEventID (String, 38) – Foreign key relationship to a StructureOrIDSite object. ClusterBufferEventID (String, 38) – Foreign key relationship to a ClusterBuffer feature.</p>
<p>Relationships: (cardinality, optionality, attributes, composite)</p>	<p>DOTClassSegmentAudit: DOTClassSegment is 1:M with DOTClassSegmentAudit StationSeriesDOTClassSegment: DOTClassSegment is M:1 with StationSeries DOTClassSegment: DOTClassSegment is M:1 with DOTClass StructureOrIDSiteDOTClassSgtMN: DOTClassSegment is M:N with StructureOrIDSite StructureOrIDSiteDOTClassSgt1M: DOTClassSegment is M:1 with StructureOrIDSite ActivityDOTClassSegment: DOTClassSegment is M:1 with Activity ClusterBufferDOTClassSgmnt: DOTClassSegment is M:1 with ClusterBuffer</p>
<p>SubTypes:</p>	<p>--</p>

8.2.5 HCACorridor Concrete Class.

- **Change** – Add HCACorridor class to support HCA analysis (Full Model)
- **Reasoning** – The HCACorridor is a polygon representing the PIR buffer of an HCA.

Class Name:	HCACorridor
Feature Class Geometry:	Implemented as a Z-Aware Polygon feature class.
APDM Inheritance:	ESRI Object → Feature → Feature Archive → OfflineFeature
Attributes: (name, type, length, precision, scale, domain, description)	<p>ActivityEventID (String, 38) – Foreign key to an Activity object record.</p> <p>PIRFactor (Double, 15,2) – A factor used in the PIR equation that is dependent on the physical properties of the product under consideration. For dry natural gas (methane), PIRFactor = 0.69.</p> <p>PIR (Double, 15,2) – The Potential Impact Radius (PIR) used in gas High Consequence Area (HCA) analysis. The PIR is determined using the following equation: $PIR = PIRFactor * OutsideDiameter * (MAOP)^{1/2}$</p> <p>PIRT (Double, 15,2) – A tolerance applied to the PIR to account for any spatial uncertainties in the location of the centerline or surrounding structures.</p>
Relationships: (cardinality, optionality, attributes, composite)	ActivityHCACorridor: HCACorridor is M:1 with Activity
SubTypes:	--

9 Documentation Items for the White Paper

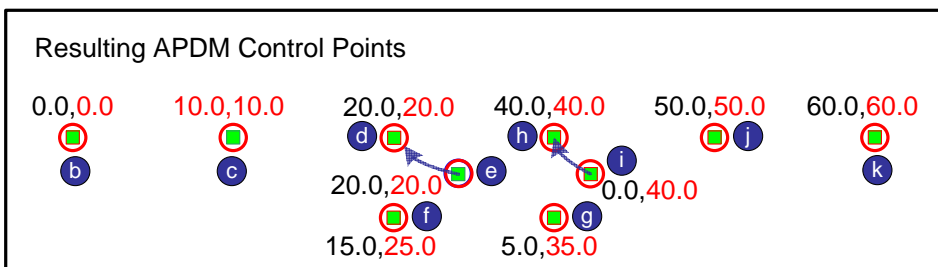
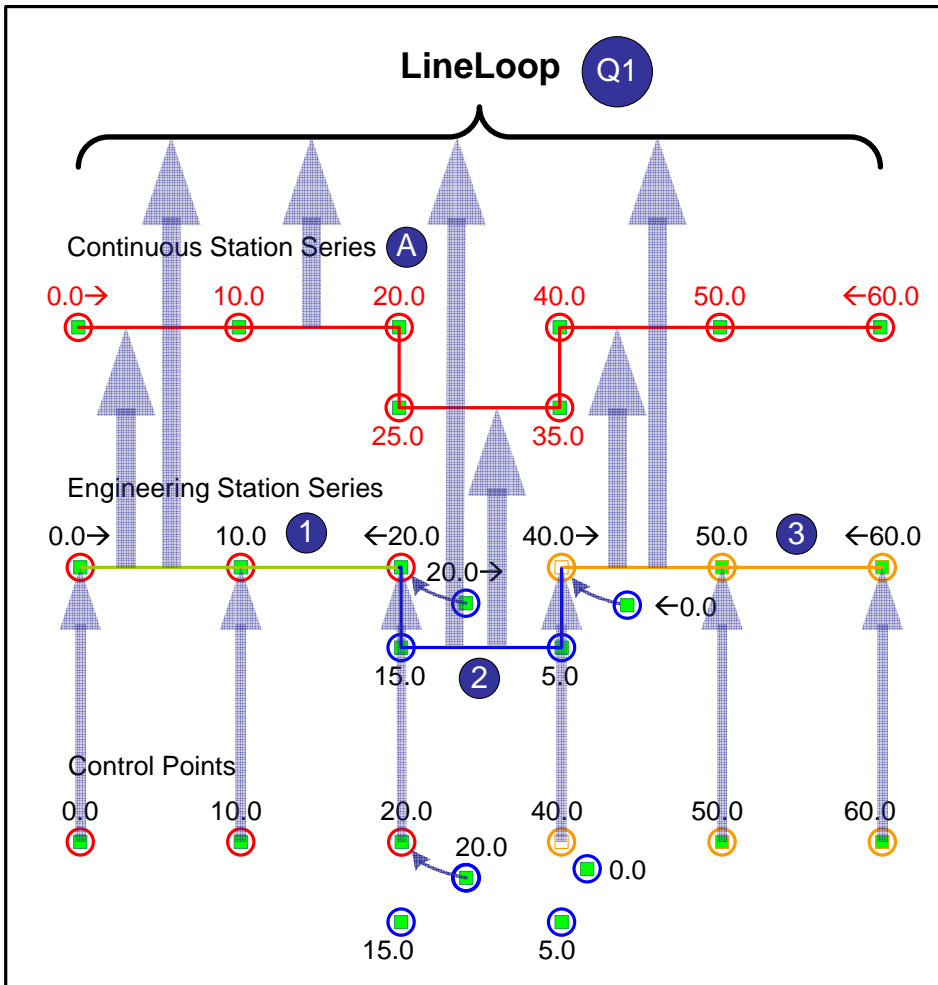
9.1 Continuous Measure and Engineering Stationing

The default implementation of APDM 5.0 utilizes Continuous Measure and Engineering Stationing. The model is designed to support more than one form of linear referencing or ‘reference mode’. Continuous Measure and Engineering Stationing are the most common forms of linear referencing in pipelines. The following table shows an example of both forms of referencing as depicted in the newly updated ReferenceMode Table.

RefMode <d>	RefModeRootName (root for FK)	RefModeMeasureRootName	RefModeUnits <d>	RefModeType <d>	RefModeBasis <d>	IsPRM	ParentRefMode <d>
Continuous	Route	Measure	Feet	Uninterrupted and Adjustable	3D Geoid	Yes	<NULL>
Engineering	Series	Station	Feet	Interrupted and Not Adjustable	3D Geoid	No	Continuous

This table outlines two forms of linear referencing: continuous measure and engineering stationing. Each linear referencing method is stored in the ReferenceMode object class as a single record or object. Therefore each object is identified by an EventID value. The Continuous Measure object has a RefMode of ‘Continuous’. This value is derived from the clRefMode domain. This domain value is applied to the RefMode attribute of the StationSeries feature class. The RefModeMeasureRootName describes the root name used for all ‘Measure’ attributes in each Online (and the StationSeries and ControlPoint) feature class. An OnlinePoint feature class will have a Measure field that will contain the ‘measure’ value of that point along a particular ‘Continuous’ measure StationSeries feature. The measure units for this reference mode are feet. The basis for the distance between the vertices or control points in the station series for this reference mode is 3D Geoid. The behavior or spatial integrity of each station series feature for this reference mode is ‘Uninterrupted and Adjustable’. This means that there is one and only one continuous measure station series for a given LineLoop. The continuous measure station series cannot be broken into two or more features per LineLoop. The EndMeasure for each continuous measure station series is based on the cumulative distance from start to end for the station series starting at the BeginMeasure value for this feature. The IsPRM field indicates that ‘continuous measure’ reference mode is the primary reference mode for the ‘engineering stationing’ reference mode. This has several ramifications. First, all child engineering stationing station series must comprise the same geometry as the parent continuous measure station series. This means that the position of the vertices from each child station series must match the position of those in the parent. The cumulative stationing of all child engineering stationing station series must equal that to the total measure of the parent continuous measure station series (EndMeasure – BeginMeasure). Second, since the child engineering stationing StationSeries belong to a ReferenceMode that is ‘Interrupted and Non-Adjustable’ this means that one or more of these station series features can be connected end-to-end to form the same route geometry as the geometry of the parent continuous measure station series feature. The parent station series geometry is comprised of the geometries of the child station series features connected end-to-end. The continuous measure station series are considered the parent reference mode so there is no ParentRefModeEventID value. Third, the RefModeRootName indicates the root name for the foreign key attribute in each Online feature class linking the feature to the StationSeries feature class and in particular the station series that is used to derive the ‘RefModeMeasureRootName’ value from.

RefMode <d>	RefModeRootName (root for FK)	RefModeMeasureRootName	RefModeUnits <d>	RefModeType <d>	RefModeBasis <d>	IsPRM	ParentRefMode <d>
Continuous	Route	Measure	Feet	Uninterrupted and Adjustable	3D Geoid	Yes	<NULL>
Engineering	Series	Station	Feet	Interrupted and Not Adjustable	3D Geoid	No	Continuous



The second reference mode – Engineering Station has a unique EventID GUID value. The RefMode is ‘Engineering’. All ‘Engineering’ station series features representing this reference mode will have a similar value in the RefMode attribute of the StationSeries feature class. The RefModeMeasureRootName is ‘Station’ which is the attribute containing the measure or station value for each OnlineFeature located along this StationSeries. The RefMode units are feet. The distances along the StationSeries are calculated by using a 3D Geoid. The RefModeType is ‘Interrupted and Adjustable’ meaning that one or more ‘Engineering Station’ StationSeries linked end-to-end will comprise the geometry of the parent StationSeries feature. The ‘Engineering Stationing’ reference mode is not the Primary Reference Mode and it will have the GUID of the Parent Reference Mode record in the ParentRefModeEventID attribute. Lastly, the RefModeRootName, or foreign key attribute root name is listed in the RefModeRootName.

The RefModeRootName is not only the root of the attributes in

Online features it also contains terminology that describes the actual station series features. Each Continuous Measure station series feature is really a ‘Continuous Measure Route’ where each Engineering Stationing station series feature is really an ‘Engineering Station Series’. These are common terms used to describe station series features in the pipeline industry.

The following diagram illustrates the spatial relationship between control points, ‘engineering station series’ and ‘continuous measure routes’. The diagram also shows how the combination of control points, series and routes forms a ‘physical’ LineLoop object in the APDM.

The bottom of the two diagrams shows a set of control points. APDM 5.0 control points now contain an attribute for each reference mode. The default implementation of ‘continous measure’ and ‘engineering stationing’ reference modes would require two attributes. Using the ReferenceMode table example above, and using the RefModeMeasureRootName values, these attributes will be called ‘MeasureValue’ and ‘StationValue’. The Value is appended to the Root names to differentiate the ControlPoint feature class from regular online feature classes. For each control point there are two ‘measure’ values. The measure values (in red) form the Continuous Station Series. The station values (in black) form the Engineering Station Series.

Assuming that the control points in the top diagram form a single LineLoop comprised of three ‘engineering’ station series; then the middle sketch shows the formation of the ‘Engineering Station’ series feature. Note that the order of stationing for these features (in a ‘Interrupted and Non-Adjustable’ reference mode) can be ascending or descending. The stationing values or measure values or M values for each StationSeries feature must be montonically increasing but the direction of the ‘interrupted’ child station series ‘measure’ values is independent of the parent continuous station series.

The middle and the top routes in the top diagram show the relationship between the ‘Continuous Measure’ routes and the underlying ‘Interrupted Engineering Station’ series. Engineering Series 1 links at it’s end point to the end point of Engineering Series 2 which links at it’s begin point to Engineering Series 3 to form the same geometry route as the ‘Continuous Measure’ Route A (in the top drawing). Although the continuous measure route is the parent reference mode it is generated and derived form the underlying engineering station series which is in-turn derived from the control points that form the engineering station series.

In the APDM 5.0, duplicate control points have been merged. Each control point will contain one attribute for each reference mode. The only time that control points are duplicated are at ‘equations’ representing the linking of two ‘interrupted’ style station series belonging to the same parent ‘non-interrupted’ style station series. The lower diagram (above) now shows control points (b-k) with ‘engineering’ station value (black) and a ‘continuous’ measure value (red).

The following three tables lists the resulting LineLoop, StationSeries and ControlPoint features described above in their respective table views based on the ‘ReferenceMode’ example (used above).

LineLoop	
Attribute	Value
ObjectID	1
GlobalID	{A298F545-4209-4CA5-9E2F-CE7F8C50E2A3}
EventID (pk)	{F3004B6A-40A6-49A6-B951-7F4F15D27E7E}
CreatedBy	Pcgv
CreatedDate	10/05/2009
EffectiveFromDate	1/1/2009
EffectiveToDate	<Null>
HistoricalState <d>	Current
LastModified	10/05/2009
ModifiedBy	Pcgv
OriginEventID	<Null>
ProcessFlag	<Null>
Remarks	APDM 5.0 LineLoop Example
OperationalStatus <d>	Active
LineName	Q1
LineType <d>	Transmission
LineLevel	2
LineFunction <d>	Mainline

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LineOrder	1
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StationSeries				
Attribute	Value	Value	Value	Value
ObjectID	1	2	3	4
Shape				
GlobalID	{81D21CE3-6414-4DF8-8035-FD52804B5DDD}	{73B57D7B-195F-4940-8E0F-0A1B6542F6C3}	{ECD9C22F-855A-483A-93F3-8E618F1C5E78}	{10DE1E6D-43E3-45CA-A50B-CA7F5E2127FB}
EventID (pk)	{4AE67B70-2B52-4DED-89D8-6E8C88CAFC2A}	{8914F122-C505-4A4F-B335-2DBF7F0D4140}	{85CE58EB-0F7B-4EF3-9584-36F23B3D0461}	{789633DF-727C-4CD0-B216-9E5EBF5507B9}
CreatedBy	Pcgv	Pcgv	Pcgv	Pcgv
CreatedDate	10/05/2009	10/05/2009	10/05/2009	10/05/2009
EffectiveFromDate	1/1/2009	1/1/2009	1/1/2009	1/1/2009
EffectiveToDate	<Null>	<Null>	<Null>	<Null>
HistoricalState <d>	Current	Current	Current	Current
LastModified	10/05/2009	10/05/2009	10/05/2009	10/05/2009
ModifiedBy	Pcgv	Pcgv	Pcgv	Pcgv
OriginEventID	<Null>	<Null>	<Null>	<Null>
ProcessFlag	<Null>	<Null>	<Null>	<Null>
Remarks	APDM 5.0 Continuous StationSeries Example	APDM 5.0 Engineering StationSeries Example	APDM 5.0 Engineering StationSeries Example	APDM 5.0 Engineering StationSeries Example
GroupEventID	<Null>	<Null>	<Null>	<Null>
BeginMeasure	0	0	20	40
BeginStation	<Null>	0	20	40
EndMeasure	60	20	40	60
EndStation	<Null>	20	0	60
OperationalStatus <d>	Active	Active	Active	Active
SeriesName				
SeriesOrder	1000	1000	2000	3000
ParentSeriesEventID (fk)	<Null>	{4AE67B70-2B52-4DED-89D8-6E8C88CAFC2A}	{4AE67B70-2B52-4DED-89D8-6E8C88CAFC2A}	{4AE67B70-2B52-4DED-89D8-6E8C88CAFC2A}
LineLoopEventID (fk)	{F3004B6A-40A6-49A6-B951-7F4F15D27E7E}	{F3004B6A-40A6-49A6-B951-7F4F15D27E7E}	{F3004B6A-40A6-49A6-B951-7F4F15D27E7E}	{F3004B6A-40A6-49A6-B951-7F4F15D27E7E}
FromConnectionStationValue	<Null>	<Null>	<Null>	<Null>
FromSeriesEventID	<Null>	<Null>	<Null>	<Null>
ToConnectionStationValue	<Null>	<Null>	<Null>	<Null>
ToSeriesEventID	<Null>	<Null>	<Null>	<Null>
RefMode	Continuous	Engineering	Engineering	Engineering

Note that all four station series features are related to a single line loop via the LineLoopEventID attribute. Note also that all three 'Engineering' series are related to the single 'Continuous' route feature using the 'ParentSeriesEventID'. No relationship class exists for this relationship; it is a logical relationship only. ESRI does not currently support self-relates within the Geodatabase. But it illustrates the point that the 'engineering' station series are children of the 'continuous' series by virtue of the values in the RefMode attribute. Correspondingly this relationship is further defined by the example ReferenceMode table provided above.

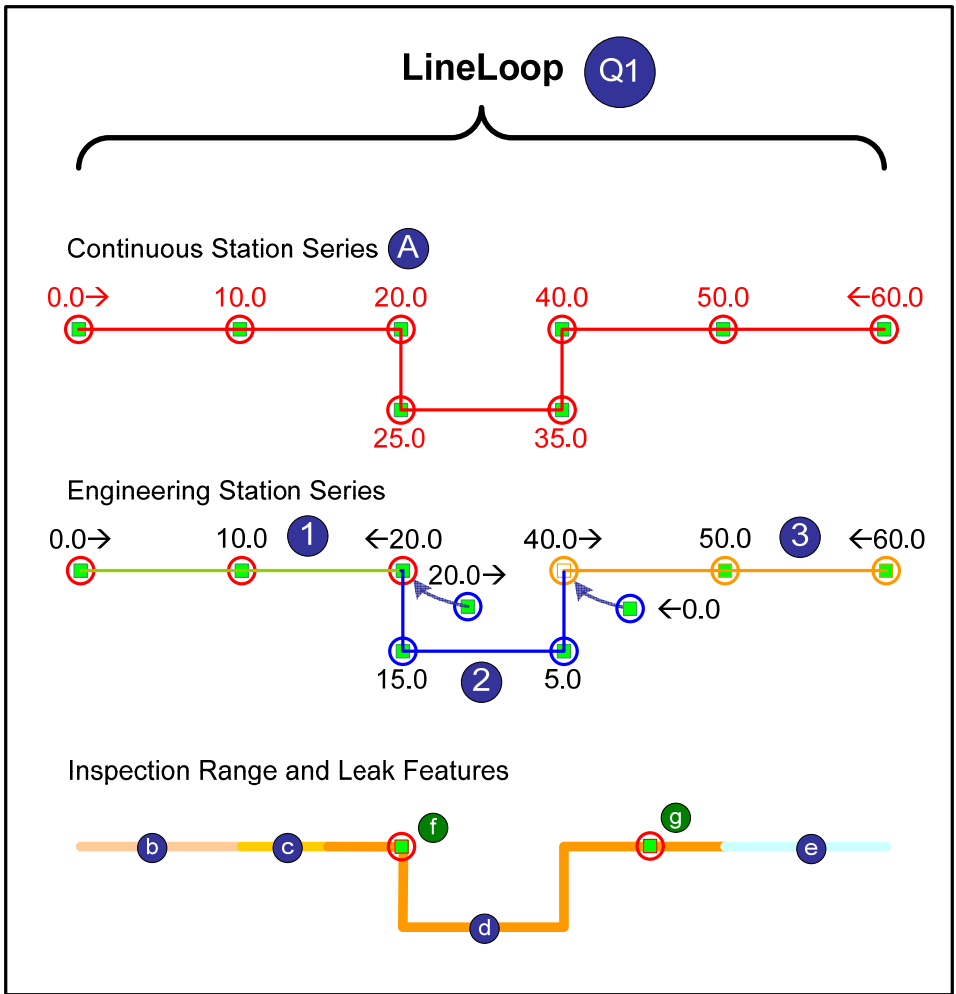
ControlPoint										
Attribute	Value	Value	Value	Value	Value	Value	Value	Value	Value	Value
ObjectID	1	2	3	4	5	6	7	8	9	10
Shape										
GlobalID	GUID	GUID	GUID	GUID	GUID	GUID	GUID	GUID	GUID	GUID
EventID (pk)	GUID	GUID	GUID	GUID	GUID	GUID	GUID	GUID	GUID	GUID
CreatedBy	Pcgv	Pcgv	Pcgv	Pcgv	Pcgv	Pcgv	Pcgv	Pcgv	Pcgv	Pcgv
CreatedDate	10/05/2009	10/05/2009	10/05/2009	10/05/2009	10/05/2009	10/05/2009	10/05/2009	10/05/2009	10/05/2009	10/05/2009
EffectiveFromDate	1/1/2009	1/1/2009	1/1/2009	1/1/2009	1/1/2009	1/1/2009	1/1/2009	1/1/2009	1/1/2009	1/1/2009
EffectiveToDate	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>
HistoricalState <d>	Current	Current	Current	Current	Current	Current	Current	Current	Current	Current
LastModified	10/05/2009	10/05/2009	10/05/2009	10/05/2009	10/05/2009	10/05/2009	10/05/2009	10/05/2009	10/05/2009	10/05/2009
ModifiedBy	Pcgv	Pcgv	Pcgv	Pcgv	Pcgv	Pcgv	Pcgv	Pcgv	Pcgv	Pcgv
OriginEventID	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>
ProcessFlag	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>

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Remarks	b	c	d	e	f	g	h	i	j	k
OperationalStatus <d>	Active	Active	Active	Active	Active	Active	Active	Active	Active	Active
RouteEventID (fk)	{4AE67B70-2B52-4DED-89D8-6E8C88CAF2A}	{4AE67B70-2B52-4DED-89D8-6E8C88CAFC2A}	{4AE67B70-2B52-4DED-89D8-6E8C88CAFC2A}	{4AE67B70-2B52-4DED-89D8-6E8C88CAFC2A}	{4AE67B70-2B52-4DED-89D8-6E8C88CAFC2A}	{4AE67B70-2B52-4DED-89D8-6E8C88CAFC2A}	{4AE67B70-2B52-4DED-89D8-6E8C88CAFC2A}	{4AE67B70-2B52-4DED-89D8-6E8C88CAFC2A}	{4AE67B70-2B52-4DED-89D8-6E8C88CAFC2A}	{4AE67B70-2B52-4DED-89D8-6E8C88CAFC2A}
MeasureValue	0	10	20	20	25	35	40	40	50	60
SeriesEventID (fk)	{8914F122-C505-4A4F-B335-2DBF7F0D4140}	{8914F122-C505-4A4F-B335-2DBF7F0D4140}	{8914F122-C505-4A4F-B335-2DBF7F0D4140}	{85CE58EB-0F7B-4EF3-9584-36F23B3D0461}	{85CE58EB-0F7B-4EF3-9584-36F23B3D0461}	{85CE58EB-0F7B-4EF3-9584-36F23B3D0461}	{85CE58EB-0F7B-4EF3-9584-36F23B3D0461}	{789633DF-727C-4CD0-B216-9E5EBF5507B9}	{789633DF-F-727C-4CD0-B216-9E5EBF5507B9}	{789633DF-727C-4CD0-B216-9E5EBF5507B9}
StationValue	0	10	20	20	15	5	0	40	50	60
Point_X	0.00	10.0	20.0	20.0	20.0	30.0	30.0	30.0	40.0	50.0
Point_Y	0.00	0.00	0.00	0.00	-5.0	-5.0	0.00	0.00	0.00	0.00
Point_Z	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CLControl <d>	No	No	No	No	No	No	No	No	No	No
CLStationEditResponse <d>	Assigned	Assigned	Assigned	Assigned	Assigned	Assigned	Assigned	Assigned	Assigned	Assigned
CLXYEditResponse <d>	Assigned	Assigned	Assigned	Assigned	Assigned	Assigned	Assigned	Assigned	Assigned	Assigned
CLZEditResponse <d>	Assigned	Assigned	Assigned	Assigned	Assigned	Assigned	Assigned	Assigned	Assigned	Assigned
SymbolRotation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ControlPointAngle	0.0	0.0	0.0	0.0	-90.0	+90.0	+90.0	0.0	-90	0.0
ControlPointType <d>	PI	PI	PI	PI	PI	PI	PI	PI	PI	PI
PIDirection <d>	None	None	None	RT	LT	LT	RT	None	None	None

All control points belong to the same ‘continuous’ measure route as denoted by the GUID values in the RouteEventID foreign key attribute to the StationSeries EventID attribute. All control points belong to one and only one engineering series feature. Note that control points D and E and control points H and I are both located at the same coordinates (yellow cells) but belong to different engineering series features (blue text) using the SeriesEventID foreign key attribute to the StationSeries EventID attribute. No two control points will share both the same MeasureValues and StationValues for a given route.

The following diagram and tables show examples of four online features; three InspectionRange features and four leak features. These examples show both the spatial position of these features but also the tabular view of how they are stored in the APDM as Online Polyline and Online Point features.



In this example Inspection Range features (b,c,d,e) and Leak features (f, g) are located on LineLoop Q1. In APDM 5.0 both the measure values from Continuous Station Series A and station values from Engineering Station Series 1, 2 and 3 are recorded with the features.

The following tables illustrate both sets of features and the FK relationships between those features and the StationSeries feature class.

Each inspection range feature belongs on the Q1 route as denoted by the RouteEventID foreign key to the EventID field in the StationSeries feature class. This foreign key value corresponds to the EventID value for the continuous station series feature in the Station Series Feature class.

InspectionRange				
Attribute	Value	Value	Value	Value
ObjectID	1	2	3	4
Shape				
GlobalID	{F34E196E-67E5-42A3-A872-B77FD5DE15E8}	{59C8A169-3578-4118-AAD3-FF6F79FEBD93}	{061FE0EC-1D1E-4CDC-976E-5A938FB7ECE3}	{811062D1-E1C6-4A5E-8921-1C5C8BC8492D}
EventID (pk)	{76F605CD-6FB5-452C-8947-2C64E9C76D5D}	{4BE3CB84-7E7A-430F-AAFD-3F6CA20DF9E2}	{60FABB8B-7148-404F-90F5-B1A14F0320A0}	{E34B4F7C-2DFB-482F-9047-A12E830BFA1E}
CreatedBy	Pcgv	Pcgv	Pcgv	Pcgv
CreatedDate	10/05/2009	10/05/2009	10/05/2009	10/05/2009
EffectiveFromDate	1/1/2009	1/1/2009	1/1/2009	1/1/2009
EffectiveToDate	<Null>	<Null>	<Null>	<Null>
HistoricalState <d>	Current	Current	Current	Current
LastModified	10/05/2009	10/05/2009	10/05/2009	10/05/2009
ModifiedBy	Pcgv	Pcgv	Pcgv	Pcgv
OriginEventID	<Null>	<Null>	<Null>	<Null>
ProcessFlag	<Null>	<Null>	<Null>	<Null>
Remarks	APDM 5.0 InspectionRange Example	APDM 5.0 InspectionRange Example	APDM 5.0 InspectionRange Example	APDM 5.0 InspectionRange Example
CLEditResponse <d>	Relative	Relative	Relative	Relative
CLValidityTolerance	0.00	0.00	0.00	0.00
RouteEventID (fk)	{4AE67B70-2B52-4DED-89D8-6E8C88CAFC2A}	{4AE67B70-2B52-4DED-89D8-6E8C88CAFC2A}	{4AE67B70-2B52-4DED-89D8-6E8C88CAFC2A}	{4AE67B70-2B52-4DED-89D8-6E8C88CAFC2A}
BeginMeasure	0	10	15	50
EndMeasure	10	15	50	60
BeginStation	0	10	15	50
EndStation	10	15	50	60
BeginSeriesEventID	{73B57D7B-195F-4940-8E0F-0A1B6542F6C3}	{73B57D7B-195F-4940-8E0F-0A1B6542F6C3}	{73B57D7B-195F-4940-8E0F-0A1B6542F6C3}	{789633DF-727C-4CD0-B216-9E5EBF5507B9}
EndSeriesEventID	{73B57D7B-195F-4940-8E0F-0A1B6542F6C3}	{73B57D7B-195F-4940-8E0F-0A1B6542F6C3}	{789633DF-727C-4CD0-B216-9E5EBF5507B9}	{789633DF-727C-4CD0-B216-9E5EBF5507B9}
Status	Active	Active	Active	Active
InspectionDate	10/05/2009	10/05/2009	10/05/2009	10/05/2009

Note how each inspection range online polyline feature also relates to one or two ‘engineering’ station series features in the StationSeries feature class. The GUID values in the BEginSeriesEventID and EndSeriesEventID fields relate to one or two station series of ‘engineering’ RefMode type in the StationSeries feature class. Note that some linear events start on one engineering station series and end on another engineering station series (as denoted by the colored cells matching the color of the respective series in the drawings above).

Leak		
Attribute	Value	Value
ObjectID	1	2
Shape		
GlobalID	{FBE90BBD-B6B7-49D1-828D-3E547ACA19C2}	{165AB795-863E-426C-883B-862B9A022F77}
EventID (pk)	{141DE41D-05B1-4693-8862-0A95C40D1A75}	{64756066-C5DF-4EAE-917F-1C92124F8873}
CreatedBy	Pcgv	Pcgv
CreatedDate	10/05/2009	10/05/2009
EffectiveFromDate	1/1/2009	1/1/2009
EffectiveToDate	<Null>	<Null>
HistoricalState <d>	Current	Current
LastModified	10/05/2009	10/05/2009
ModifiedBy	Pcgv	Pcgv
OriginEventID	<Null>	<Null>
ProcessFlag	<Null>	<Null>
Remarks	APDM 5.0 Leak Example	APDM 5.0 Leak Example
CLEditResponse <d>	Relative	Relative
CLValidityTolerance	0.00	0.00
RouteEventID (fk)	{4AE67B70-2B52-4DED-89D8-6E8C88CAFC2A}	{4AE67B70-2B52-4DED-89D8-6E8C88CAFC2A}
Measure	20	45
SeriesEventID (fk)	{8914F122-C505-4A4F-B335-2DBF7F0D4140} or {85CE58EB-0F7B-4EF3-9584-36F23B3D0461}	{789633DF-727C-4CD0-B216-9E5EBF5507B9}
Station	20.0	45
Status <d>	Active	Active
SymbolRotation	0.0	0.0
Point_X	20.0	35.0
Point_Y	0.0	0.0
Point_Z	0.0	0.0
DateRepaired	10/05/2009	10/05/2009
DateReported	10/05/2009	10/05/2009
Depth	2.3	1.2
LeakCause <d>	Some domain value ...	Some domain value ...
LeakOrigin <d>	Some domain value ...	Some domain value ...
MethodDetected <d>	Some domain value ...	Some domain value ...
RepairType <d>	Some domain value ...	Some domain value ...

9.2 Inherited Reference Mode Root Names

A reference mode is defined as a defined system of linear referencing measurement. Linear referencing is an ESRI data management construct where point or line events can be drawn or depicted along a route provided the event is contained in a table with a primary key to a PolylineM aware shape file or feature class. The event will have a second attribute indicating the measure along a particular PolylineM feature in the route feature class. Through this method, events can be drawn on-screen in ArcGIS Desktop for display purposes.

The storage and categorization of the M or measure values in a route is a reference mode. A reference mode is described by a name, the units of measure used for M (or measure) values, the basis for how the M calculated (2D or 3D distance), and how the M values of the routes and the geometry of the routes themselves behave if the geometry of a route is altered. The reference mode is also described with root names for foreign key and measure/station values that are stored as attributes in event-based classes.

The ReferenceMode table is designed to store the meta data describing the reference modes used within an APDM. This section of the document will concentrate on describing the relationships between online feature/event classes, the StationSeries feature class and the ReferenceMode metadata class using the default reference modes listed below.

RefMode <d>	RefModeRootName (root for FK)	RefModeMeasureRootName	RefModeUnits <d>	RefModeType <d>	RefModeBasis <d>	IsPRM	ParentRefMode <d>
Continuous	Route	Measure	Feet	Uninterrupted and Adjustable	3D Geoid	Yes	<NULL>
Engineering	Series	Station	Feet	Interrupted and Not Adjustable	3D Geoid	No	Continuous

The table above lists the two default reference modes for APDM 5.0: Continuous and Engineering. Blue is used to define information describing the ‘continuous’ reference mode and ‘green’ is used to define the information describing the ‘engineering’ reference mode.

The RefModeMeasureRootName field in the ReferenceMode metadata class contains the ‘root’ name used to store the measure or station values in Online event/feature classes. A point event requires a single ‘measure’ attribute for each reference mode. The name of the ‘measure’ attribute for each reference mode is contained in the RefModeMeasureRootName column. The name of the foreign key attribute in the point event/feature class is stored in the RefModeRootName column. Based on the values in the above reference mode table a point event/feature class in APDM must have the following fields:

- RouteEventID – FK to a Continuous station series feature in the StationSeries feature class.
- Measure – contains the measure value that is used to locate the point along the Continuous station series feature.
- StationEventID – FK to a Engineering station series feature in the StationSeries feature class.
- Station – contains the measure/station value that is used to locate the point along the Engineering station series feature.

A polyline event requires two ‘measure’ attributes for each reference mode. The root name for these attributes is likewise contained in the RefModeMeasureRootName column for each reference mode. Since a linear event requires a begin and end attributes to define it’s position along the route two attributes are added to each online polyline event/feature class with ‘Begin’ and ‘End’ added to the RefModeMeasureRootName. Similarly the name of the foreign key attribute in the point event/feature class is stored in the RefModeRootName column. The ‘Continuous’ reference mode is the Primary Reference Mode and it is defined as ‘Uninterrupted and

Adjustable’ inferring that only one ‘continuous’ station series feature can exist per lineloop. There only one foreign key field is required in each Offline polyline feature class. However, the ‘Engineering’ reference mode is ‘Interrupted and Not-Adjustable’ meaning that more than one engineering station series feature can exist for a given line loop. This means that a ‘begin’ and ‘end’ foreign key attributes must defined for each online polyline event/feature class to track the possibility of a linear event starting on one engineering station series and ending on another. Based on the values in the reference mode table on the preceding page a online polyline event/feature class in APDM must have the following fields:

- RouteEventID – FK to a Continuous station series feature in the StationSeries feature class.
- BeginMeasure – contains the measure value that is used to locate the starting point of the linear feature along the Continuous station series feature.
- EndMeasure – contains the measure value that is used to locate the ending point of the linear feature along the Continuous station series feature.
- BeginStationEventID – FK to a Engineering station series feature in the StationSeries feature class where the starting point of the linear feature is located.
- BeginStation – contains the measure value that is used to locate the starting point of the linear feature along the Engineering station series feature.
- EndStationEventID – FK to a Engineering station series feature in the StationSeries feature class where the ending point of the linear feature is located.
- EndStation – contains the measure value that is used to locate the ending point of the linear feature along the Engineering station series feature.

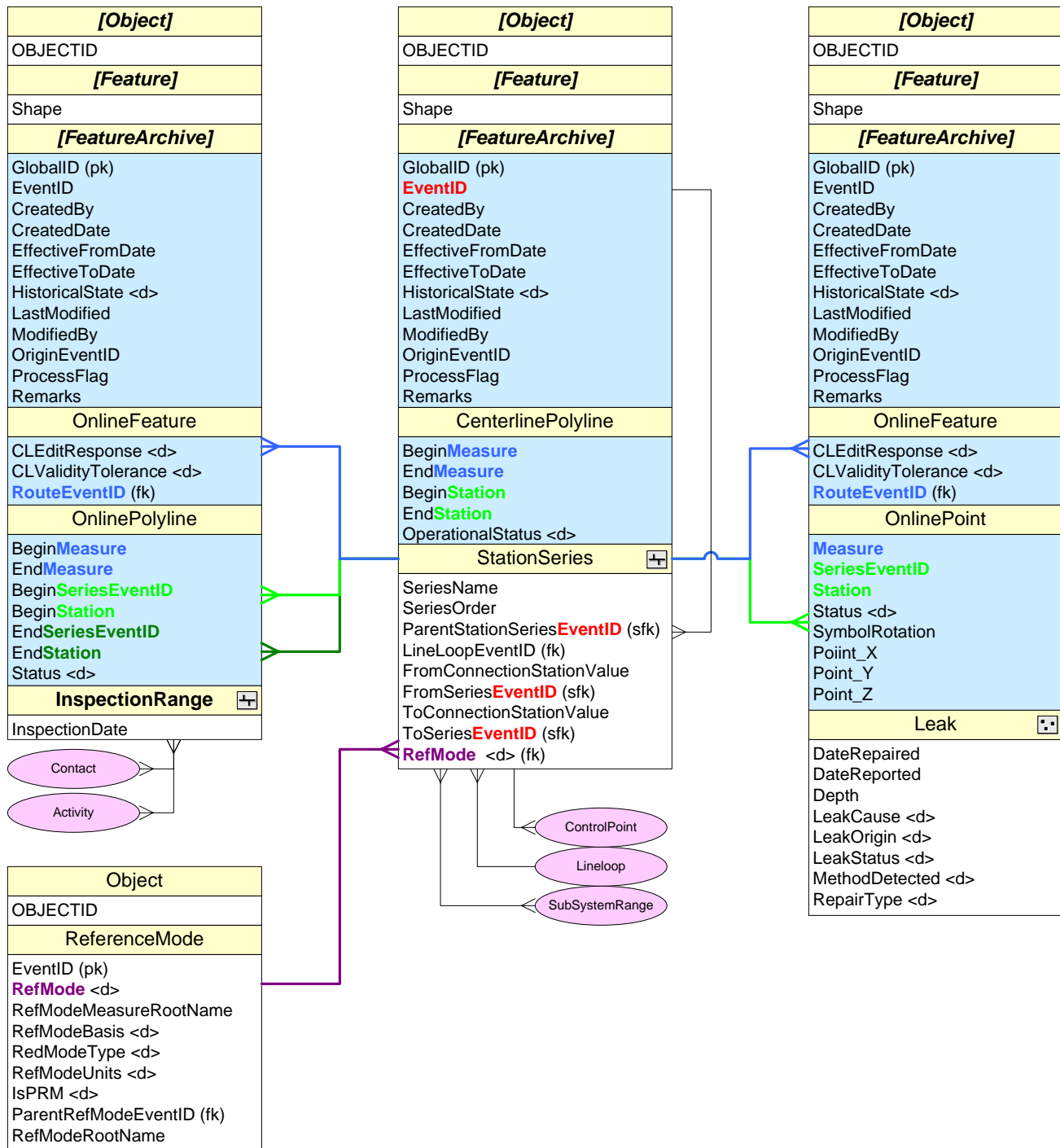
The following diagram illustrates examples of the schema for an online polyline event/feature class (InspectionRange) and a online point event/feature class (Leak). The schema for the StationSeries feature class and the ReferenceMode meta data table are also included. The relationships between the online event/feature classes are included and color coded to match the information listed in the reference mode table example. Blue lines indicate the ‘Continuous’ Route reference mode/station series relationships. Light Green indicate the BEGIN ‘Engineering’ Series reference mode/station series relationships. Dark Green indicate the END ‘Engineering’ Series reference mode/station series relationships. The RED attributes show the relationships between StationSeries features of different reference modes. For example – each StationSeries of RefMode = ‘Engineering’ will have a single ‘Continuous’ Route StationSeries parent. This relationship is defined in the ReferenceMode metadata table. Where the ‘Continuous’ reference mode is the Primary Reference Mode and it’s EventID value is stored in the ParentRefModeEventID value for the ‘Engineering’ reference mode. The foreign key value for the relationship between ‘Engineering’ series and ‘Continuous’ route StationSeries features is contained in the ParentStationSeriesEventID attribute in the StationSeries feature class. Each ‘Continuous’ station series will have a null value in this attribute. Each ‘Engineering’ station series will have the GUID value matching the EventID value of the parent ‘Continuous’ station series that it belongs to.

Also note the relationship between StationSeries and ReferenceMode using the RefMode attribute (colored in purple). The parent-child relationship between reference modes in the ReferenceMode table is reflected in a parent-child relationship between station series features in the StationSeries feature class. Every station series feature must have a RefMode value equal to a defined reference mode in the ReferenceMode metadata table. Each reference mode defined in this table will have one or more station series features of that reference mode type stored in the StationSeries feature class.

In the default implementation of APDM 5.0 using ‘Continuous’ and ‘Engineering’ as reference modes (as defined in the above ReferenceMode table example) the following rules apply:

For a given physical LineLoop:

- There must be a single continuous station series feature that comprises the entire route of the line.
 - The LineLoopEventID attribute will be populated with the EventID value of a LineLoop object.
 - The BeginMeasure and EndMeasure attributes must contain an assigned start value and the cumulative length of the route in measure units respectively.
 - The BeginStation and EndStation attributes can be null.
 - The ParentStationSeriesEventID attribute must be null.
 - The RefMode attribute must have the value of 'Continuous'
- There must be one or more engineering station series features that completely cover, without gap or overlap, the exact same path (geometry) as the parent continuous station series feature.
 - For each engineering station series:
 - The LineLoopEventID attribute will be populated with the same GUID value as the stored in the parent continuous station series feature.
 - The BeginMeasure and EndMeasure attributes will contain the measure value at those points along the parent 'Continuous' station series feature
 - The BeginStation and EndStation attributes must contain an assigned start value and the cumulative length of the engineering station series in station units respectively.
 - The ParentStationSeriesEventID attribute will contain the EventID attribute value of the parent 'Continuous' station series feature.
 - The SeriesOrder value will be populated with a sequential integer value indicating the order in which the engineering station series feature appear along the continuous route starting at the series that is found at the BeginMeasure position of the route.
 - The FromSeriesEventID and the ToSeriesEventID will be populated with the EventID values of the engineering station series that comprise the route from start to finish along the route. The first series in the string will not have a FromSeriesEventID value and the last series in the string will not have a ToSeriesEventID value.
 - The RefMode attribute must have a value of 'Engineering'

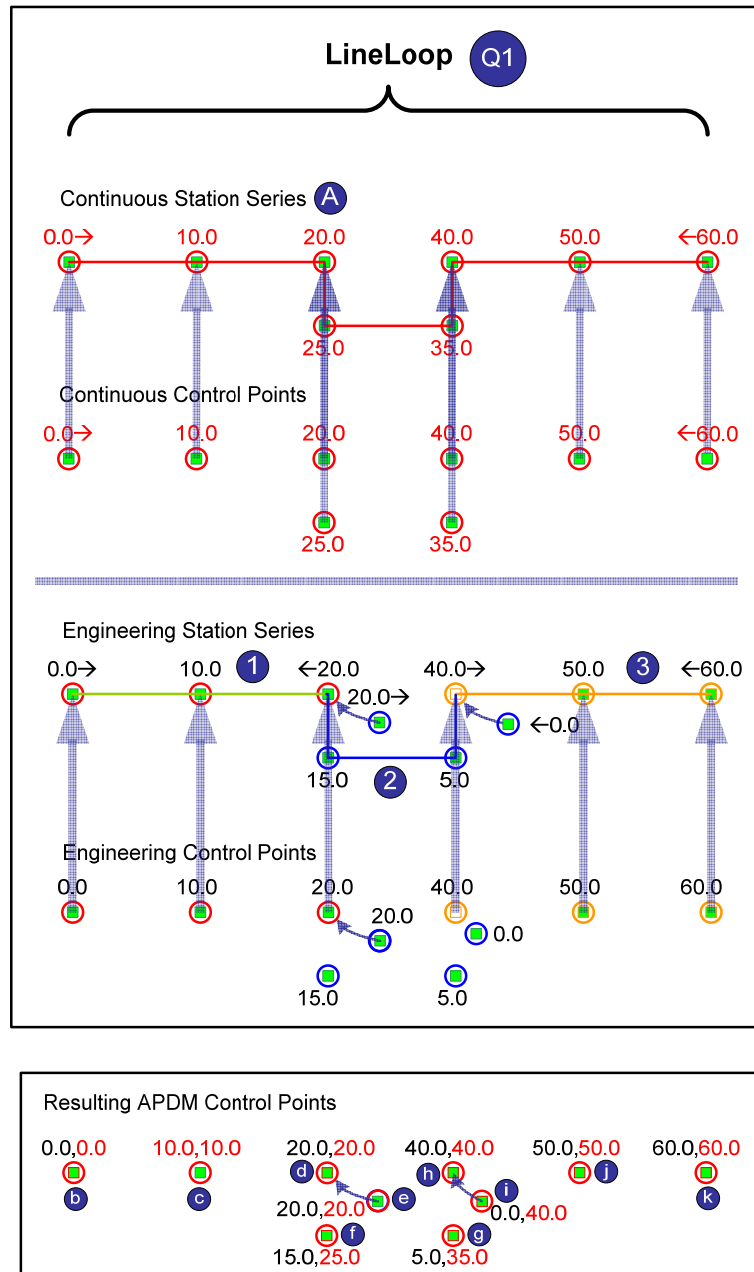


Note that the ParentStationSeriesEventID does not follow the RefModeRoot naming convention as defined in the description in the preceding pages or in the ReferenceMode metadata table. This field refers to a surrogate primary-foreign key relationship between the StationSeries feature class and itself. Currently ESRI technology do not support as self- or reflexive relationship class. The relationship is documented in the above diagram but is not physically implemented in the physical model. The values in the ParentStationSeriesEventID MUST be maintained manually or programmatically. Note that the ToSeriesEventID and the FromSeriesEventID values in the StationSeries feature class remain the same to maintain compatibility with APDM 4.0.

9.3 Removing AltRefMeasure Object Class

The addition of secondary stationing attributes in the Online event/feature classes removes the need for the AltRefMeasure object class. See the notes on GroupEventID below for further information why AltRefMeasure is required.

9.4 Merging Control Points



Only a single set of control points will be maintained in APDM 5.0. In APDM 4.0 a complete set of control points was maintained for each station series feature. APDM5.0 default implementation requires a ‘continuous’ measure route station series be present for each physical LineLoop object in the model. Each vertex of the continuous measure route station series feature will have a control point. The control point will now contain the XYZ values of the vertex and a foreign key and measure field for each type of reference mode listed in the ReferenceMode table.

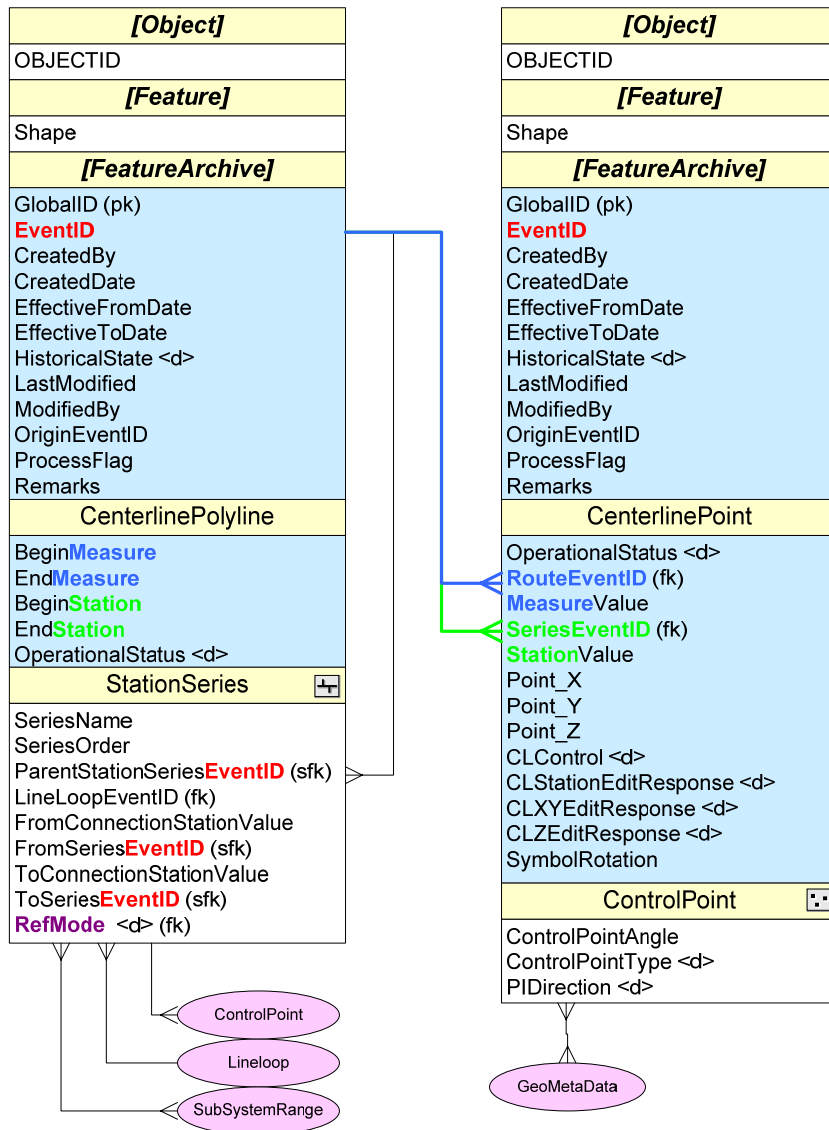
This diagram shows in APDM 4.0 where for each station series one set of control points would be maintained for both the continuous and engineering station series. In this example a minimum of two control points would be stored in the APDM for the same XYZ location. At the equation points, where two engineering station series abut against each other, there will be a minimum of three control points – one continuous control point, two engineering control points – one at the end of the first engineering station series, one at the beginning of the second engineering station series.

In APDM 5.0 control points sharing the same XYZ coordinate but different reference modes are merged into a single control point. In the diagram below the APDM 5.0 control points are shown. Instead of duplicate points being maintained for all sets of control points only a single point is saved. Non-equation control points B, C, F, G, J, and K are merged into a single point. Equation

points D, E, H, I now require two points – one for each engineering station series at the equation, rather than the three points that were required in APDM 4.0.

To facilitate the merging of control points new attributes are required to manage this data. The diagram in the following page shows the new additions to the ControlPoint feature class schema. Each control point must have

a two foreign key attributes – one for each reference mode. Each Control point must have two measure or station value attributes – one for each reference mode.



The ControlPoint feature class now contains the EventID value of both the Continuous Route Station series and the Engineering Station series feature that it belongs to. The ControlPoint feature also contains a MeasureValue and a StationValue for each of these station series features.

9.5 Additional Reference Modes

The APDM 5.0 allows for the use of additional reference modes or the use of a single reference mode. The definition of reference modes in the ReferenceMode metadata table and the creation StationSeries features for each of these reference mode allow operators to define reference modes and series as needed to suit their business needs.

The current implementation of APDM 5.0 uses Continuous Measure and Engineering Stationing as default reference modes. The behavior that describes each is listed in the ReferenceMode metadata table.

9.6 MetaData Table Changes

Although every attempt was made to not delete fields but rather add to the model the

APDM MetaData tables underwent some changes that involved deleting and altering schema. The most notable are the re-write of the ReferenceMode and APDMClass tables. The former is described in detail above, the latter was altered to make it more generic and not reference APDM explicitly in the table, attribute and domain names.