CHAPTER 9 – GIS PROGRAM

9.1   Introduction

This chapter documents the methodology used to develop the geodatabases for GWA. The initial step was to assess the current status of GWA's GIS, which was developed for GWA in the early 1990s. Because it is unclear how that system was developed and whether the data format would be compatible with new software systems, creating a new GIS system was determined to be the best course of action.

An assessment was performed to determine the potential uses of GWA's GIS system. The most immediate uses for the data collected in the GIS are:

- Location of assets in the field
- Inventory of assets
- Development of hydraulic models

With these potential uses in mind, a plan was developed to create the water and wastewater geodatabases. The water and wastewater geodatabases are based on the Environmental Systems Research Institute, Incorporated (ESRI), geodatabase models and customized by Integrated Information Systems, Incorporated (IIS). The process of developing GWA's GIS is depicted in Figure 9-1, GIS Data Development Diagram. The steps taken can be traced along the geodatabase development, documentation, and training paths. The development of the geodatabases for both water and wastewater included the following elements:

- Database design
- Prototype
- Data Input
- Quality Assurance/Quality Control (QA/QC)
- Field validation

These elements will be discussed in more detail in the following parts of this chapter. The later sections document the sources of data, the tools, and the training that the GWA staff need to update and improve the organization's GIS system.

An additional geodatabase was needed to provide background and reference layers for mapping. A base map geodatabase was developed using data from the Government of Guam, Bureau of Statistics and Planning (BSP).

9.2   GIS Datum and Projection

The GWA geodatabases were developed using the Guam Geodetic Network 1993 (GGN93) as their projection. Other projections in use in Guam are the Guam Geodetic Triangulation Network 1963 (Guam 63) commonly used by BSP, and the Planning and World Geodetic System 84 (WGS84) used by various federal agencies. The GGN93 projection, with its units converted to feet, was selected because it is currently used by surveyors in Guam. The details of GGN93 are listed in Table 9-1.

Table 9-1 – Guam Geodetic Network 1993

Projection	Transverse Mercator
False Easting	100000.00
False Northing	200000.00
Central Meridian	144.75 (144d 45m 0s E)
Latitude of Origin	13.50 (13d 30m 0s N)
Linear Unit	Meter
Datum	North American Datum (NAD) 1983 High Accuracy Reference Network (HARN)

9.3   Geodatabase Structure

The base map and collected water and wastewater data have been stored in an ESRI geodatabase structure made up of classes and subclasses. This document is not intended to describe how geodatabases work or how they are designed; however, it is important to have a general understanding of how a geodatabase is organized. For a more complete explanation of geodatabases, refer to ESRI documentation that comes with ArcInfo ("Modeling Our World", p. 75). The following major terms are important for understanding how the getodatabases are designed and organized, as illustrated in Figure 9-2, Geodatabase Structure.

9.3.1   Geodatabase

A geodatabase is a top-level unit of geographic data containing a dataset, feature classes, object classes, and relationship classes. The geodatabases for this project are stored in a Microsoft (MS) Access personal geodatabase.

9.3.2   Feature Dataset

Feature datasets are collections of spatial data within a geodatabase. Attribute tables are the other common type of data stored within a geodatabase, but typically they are outside of the feature dataset.

9.3.3   Feature Class

A feature class is a collection of features with the same type of geometry and the same attributes. Examples of feature classes are manholes, sewer mains, and pump stations. Feature classes are the spatial entities or layers within the geodatabase. These are the major classes, at the top level, of graphical features. A description of the feature classes for each geodatabase is provided in Appendix 1J.

9.3.4   Object Class

An object class is a table in a geodatabase that is used to store a collection of objects with similar attributes and behavior, but with no location information. The population projection data table is an example of a set of data with no spatial data. The spatial data are stored in the original Census tract and block shapefile.

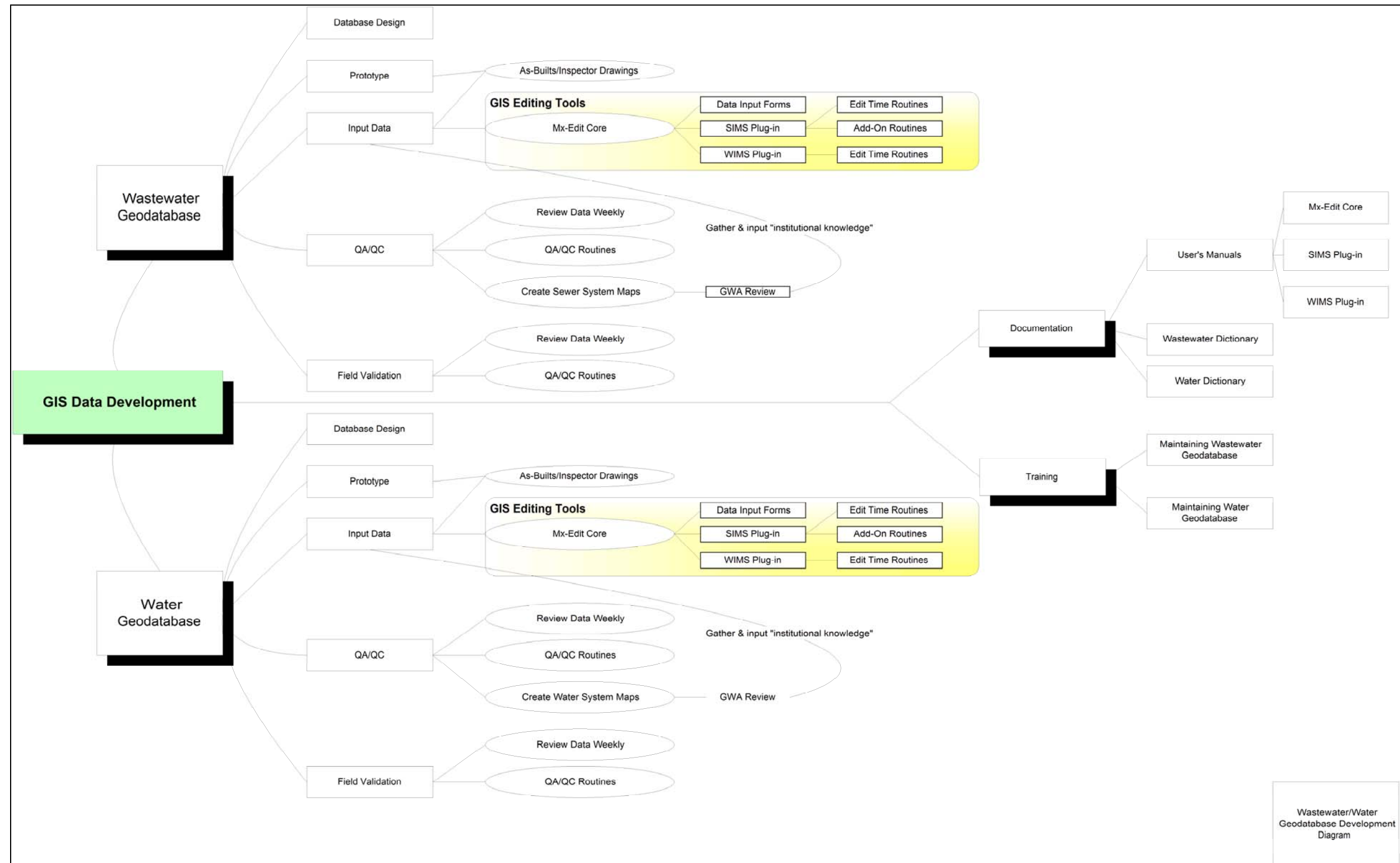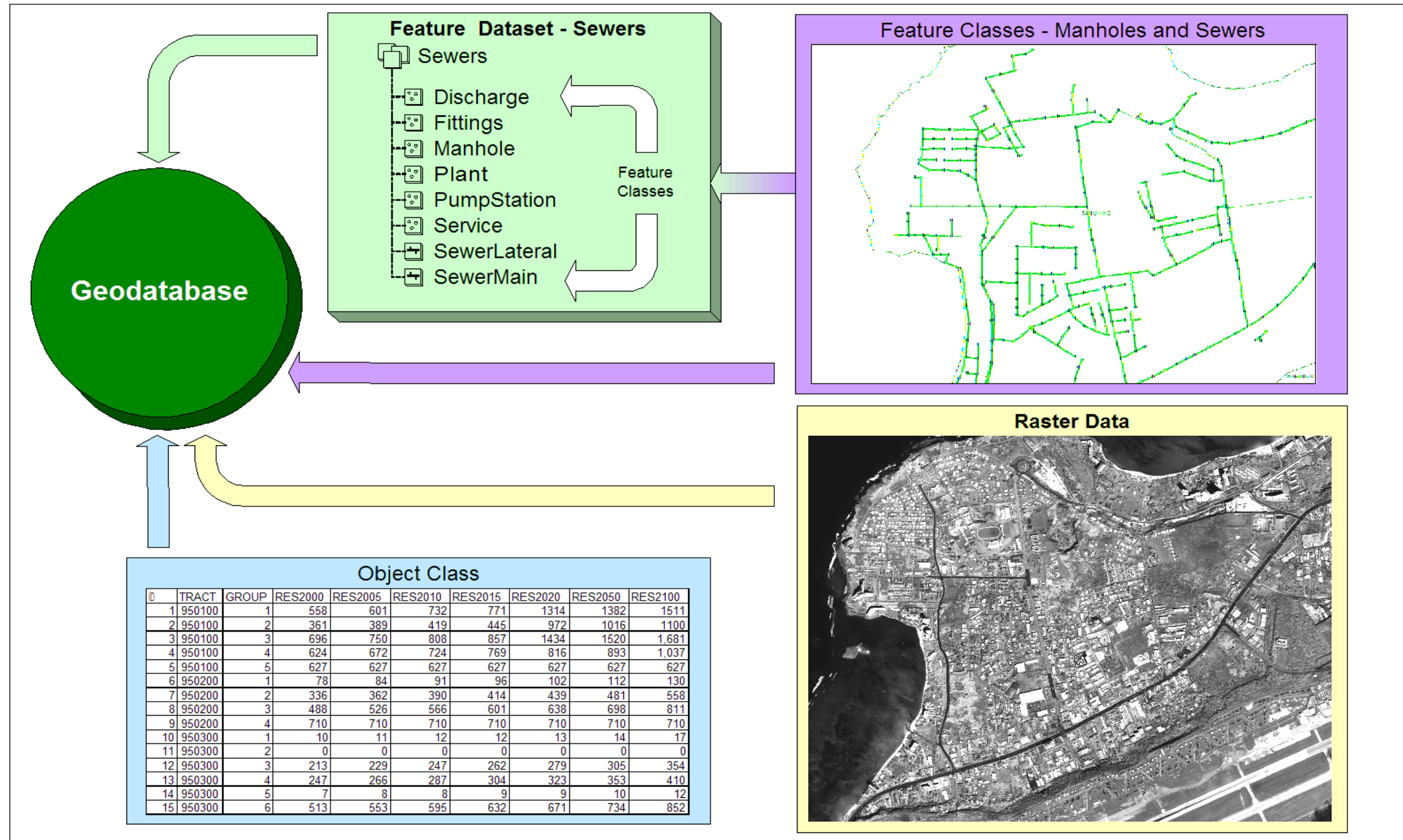Figure 9-1 – GIS Data Development Diagram

Figure 9-2 – Geodatabase Structure

Feature Dataset - Sewers
- Sewers
  - Discharge
  - Fittings
  - Manhole
  - Plant
  - PumpStation
  - Service
  - SewerLateral
  - SewerMain

Feature Classes

Geodatabase

Feature Classes - Manholes and Sewers

Raster Data

Object Class

ID	TRACT	GROUP	RES2000	RES2005	RES2010	RES2015	RES2020	RES2050	RES2100
1	950100	1	558	601	732	771	1314	1382	1511
2	950100	2	361	389	419	445	972	1016	1100
3	950100	3	696	750	808	857	1434	1520	1,681
4	950100	4	624	672	724	769	816	893	1,037
5	950100	5	627	627	627	627	627	627	627
6	950200	1	78	84	91	96	102	112	130
7	950200	2	336	362	390	414	439	481	558
8	950200	3	488	526	566	601	638	698	811
9	950200	4	710	710	710	710	710	710	710
10	950300	1	10	11	12	12	13	14	17
11	950300	2	0	0	0	0	0	0	0
12	950300	3	213	229	247	262	279	305	354
13	950300	4	247	266	287	304	323	353	410
14	950300	5	7	8	8	9	9	10	12
15	950300	6	513	553	595	632	671	734	852

9.3.5   Raster Datasets

Images and other raster datasets are an important GIS data resource that geodatabases can manage. IKONOS and Quickbird satellite imagery have been used during the development of the water and wastewater geodatabases.

9.3.6   Relationship Class

Relationship classes are associations between features and objects in a geodatabase. The relationship between the Census tract and block data and the population projection table is an example of a relationship.

9.3.7   Subtypes

Subtypes are the minor classes under each of the features classes. Table 9-2 lists the valid subtypes for the SewerMain feature class.

Table 9-2 – Example of Valid Subtypes for SewerMains

Subtype Value	Description
1	GravityST
2	ForceST
3	ModelLinkST
4	SiphonST
5	TreatmentST
6	OutfallST

9.3.8   Domains

Domains are valid values and ranges for feature class attributes. The database will only accept and store attribute data that meet the domains defined in the database. For example, a sewer manhole has valid domains, as identified in Table 9-3. Domains can be added and updated as needed. Domains are also called attribute domains.

Table 9-3 – Example of Valid Domains for ManholeType

Domain Value	Description
PLN	Plain
PRES	Pressure
DROP	Drop
SHDP	Shallow Drop
JBOX	Junction Box
CHIM	Chimney
TERM	Terminal
INJECT	Injector Manhole

9.3.9 Attributes

Attributes are the data that define a feature or object. For example, a feature class called wPressurizedMains may store pressurized water mains data. All water mains have the same attributes—Diameter, Depth, Material, GroundSurfaceType, Size, and PressureRating, together with many other attributes.

An example of how attributes, subtypes, and domains work within a feature class is illustrated in Figure 9-3.

Figure 9-3 – Feature Class Attributes, Subtypes and Domains
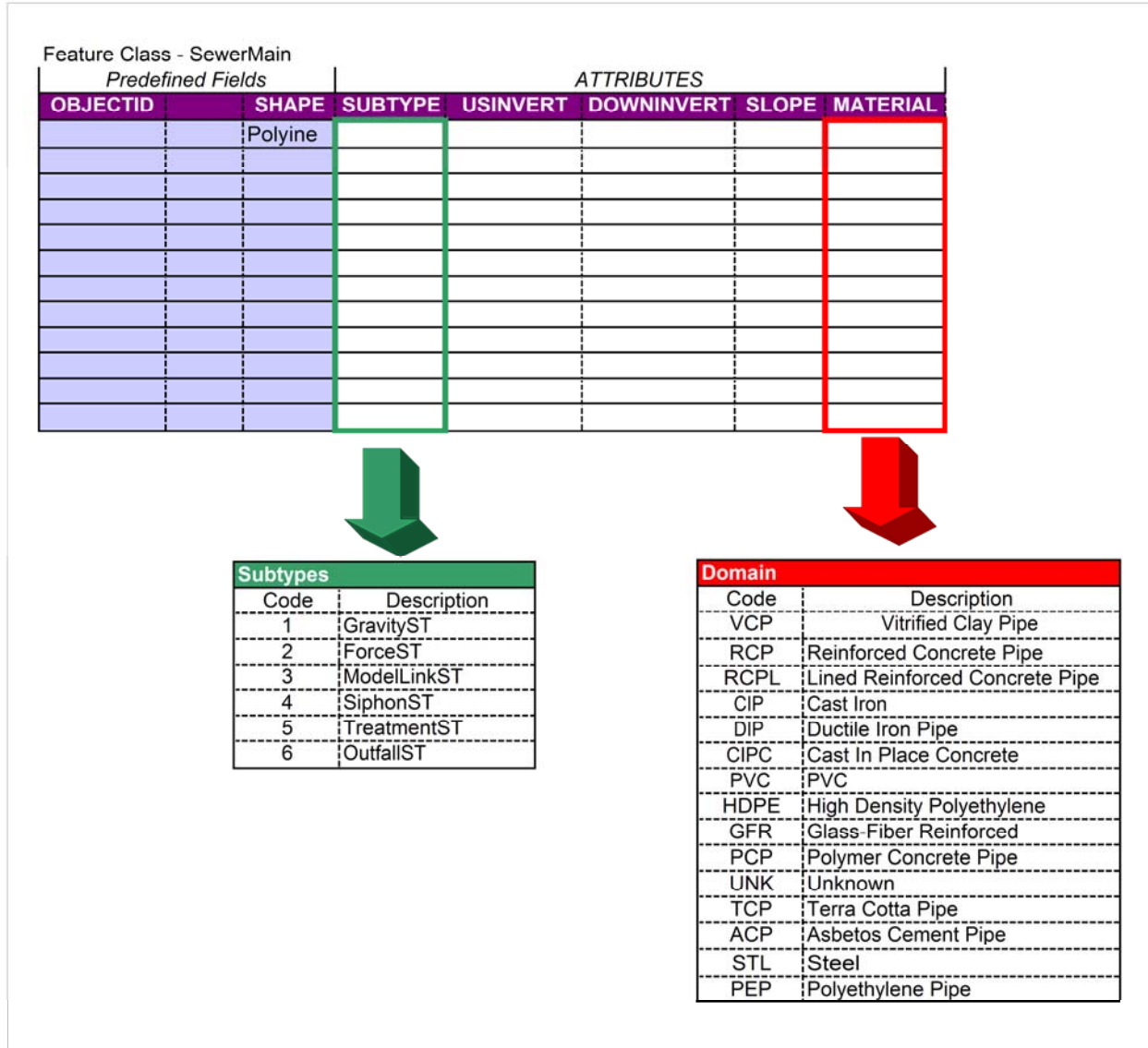
The base map, water, and wastewater geodatabases contain feature classes that support the unique data needs of each system. The following sections explore the feature classes of each geodatabase.

9.4   Base Map Geodatabase

The related GIS layers used for general mapping and analysis have been organized into a GIS geodatabase. The GIS feature layers used for the project should be inserted into the geodatabase for organization and assurance that the projection information is the same. The Guam BSP provided the following layers in the base map geodatabase:

- Wetlands
- Municipal boundaries (village boundaries)
- Landmarks
- Parcels
- Guam Island
- Census tracts
- Census blocks

BSP currently uses the Guam Geodetic Triangulation Network 1963 (GGTN 1963), datum for its data. The data must be converted to the GGN93 datum to be compatible with the water and wastewater geodatabases.

9.5   Population Projection Data Table

A population projection table was designed for reference with the field definitions that are needed for the water and wastewater system modeling tasks. This table was developed with the block group records from the original U.S. Census Block group data (bg66_d00). There are 203 block group records in this table.

This table was linked back to the Census tract and block shapefiles related by the "Tract" and "BlkGroup" fields, respectively, and used for spatial operations in GIS. The wastewater and water models require a breakdown in the types of population, such as residential, employment, and hotel or visitor, and transient population. These categories were included in this table with the base year and some target years.

9.5.1   Model Resolution

The GIS modeling used the smallest resolution of population data possible, since these numbers were used to project wastewater flow or water demand in pipes. The U.S. Census tract level data contains employment information, while the residential population exists at the smaller block group level. Employment and hotel population categories were distributed to the block group level based on research done by D.E. Consulting.

9.5.2   Population Projections and Growth Rates

Projections for residential population and employment information were forecasted every 5 years from 2005 to 2020 and for years 2050 and 2100. The population growth rates were developed by D.E. Consulting and entered into the population projection table. A more detailed discussion of the population projection and growth rate development is provided in Chapter 6 of this volume.

9.5.3   Maximum Capacity

The population projection also considered the carrying capacity or target maximum capacity or density. Growth rates based on historical growth rates cannot be applied infinitely

without exceeding reasonable capacity. Based on land use, zoning, and professional judgment from a planning perspective, D.E. Consulting determined the maximum allowable capacity for each census block. This approach prevents the water and wastewater models from projecting and distributing growth unrealistically. A maximum population capacity has been designated for each block group in each of the population categories in the fields ResCap, EmpCap, and HotelCap.

9.6   Wastewater Geodatabase

Development of the wastewater geodatabase was based on ESRI's wastewater geodatabase design and customized by IIS to meet GWA's needs. The feature classes defined in the wastewater GIS database are explained in general terms. For more information on the definitions of each feature class, refer to the Data Dictionary in Appendix 1J.

SewerMain. Sewer mains are pipe segments defined between manholes. The entire reach, from manhole to manhole is considered a sewer main reach. The direction of flow is stored within the sewer main reach. The subtypes are gravity, forcemains, outfalls, siphon, modelLinks, and treatmentLinks.

Manhole. Manholes are the junctions between sewer mains and represent the physical location of each manhole. The subtypes of manholes are plain, pressure, drop, shallow box, and junction box types.

SewerLateral. Sewer laterals in the GIS database represent the connection between the sewer mains and the parcels. Laterals must feed into gravity mains. Laterals are graphical representations and in general do not represent the actual lengths. The Actual Utility Design Length field stores the actual length from the design drawings. Laterals must extend into the parcel in order for the sewer database to be automatically updated by the parcel layer and parcel data. There are no lateral subtypes.

Plant. Treatment plants are summarized down to one connection; typically this is the location of the point of influent. The pipes in the treatment plant are not generally digitized in the GIS database, but they can be, if needed, using the treatmentLink subtype of the sewer mains feature class.

Pump Station. Pump stations are summarized down to one point. A model link should be connected to the immediate reach downstream of a pump station. Forcemains must be connected to the downstream reach of a modelLink node and reach. This format will maintain compatibility with future uses of the data with hydraulic modeling software. There are no subtypes for pump stations.

Fitting. The miscellaneous other junction types are usually defined as fittings. The most common fittings are the junctions between sewer laterals and sewer mains. The fitting subtypes are lateral fitting, plugged end, valve, test site, coupling, boundary, and cleanout.

Service. The end of a sewer lateral feature class must have a service junction. This is a special junction type that can only be on the end of laterals. The database connection rules and Sewer Information Management System (SIMS) ensure that services are only entered at these ends. The service junction is important because it stores the connection information about the lateral, (e.g., connection date, Property ID).

Discharge. Discharge locations are special locations at the outflow of a collection system, usually at the end of outfall subtypes, but may be at injection wells also.

9.7   Water Geodatabase

The water geodatabase is stored in an ESRI geodatabase structure and customized by IIS to meet GWA's needs.

Database Feature Classes. The feature classes defined in the water geodatabase are explained in general terms. For more information on the definitions of each feature class, refer to the Data Dictionary in Appendix 1J.

Anode. An anode is a feature (specifically, an electrical mechanism) that is applied to system components for the prevention of rust, pitting, and corrosion of metal surfaces that are in contact with water or soil. A low-voltage current is applied to the water or soil in contact with the metal in such a way that the electromotive force renders the metal component cathodic. Corrosion is concentrated on the anodes instead of on the associated (and protected) water system components. This type of corrosion may occur in copper, steel, stainless steel, cast iron, and ductile iron pipes.

Casing. A casing is a line protector that surrounds or encloses a water line to protect it from physical damage or other ground-based contaminants. Casings are used when installing water mains under railroad tracks, major highways, and other obstructions. Types of casings are Casement, ConduitBridge, ProtectiveTunnel, and AccessTunnel.

Casings are also the tubular structures used to maintain a well opening. Common casing materials are steel, polyvinyl chloride (PVC), and concrete. The casing feature class was not used in the GWA water geodatabase because the casing is considered to be a part of the well.

Reservoir. A reservoir feature represents an open water storage used as water supply within the water distribution system.

ScadaSensor. The ScadaSensor feature is used to remotely measure the status of network components as part of a SCADA system. SCADA systems provide alarms, responses, data acquisition, and control for collection and distribution systems. Operators use the SCADA system to monitor and adjust processes and facilities along a line where a repair has occurred. The types of spatial operations records are Leak, Maintenance, Repair, and Inspection.

ThrustProtection. The ThrustProtection class represents a type of line protector that is used to prevent pipe movement. Thrust protection is commonly implemented as thrust blocks (masses of concrete material) that are placed at bends and around valve structures. The types of thrust protection include Anchor, Blocking, Deadman, and Kicker.

UndergroundEnclosures. UndergroundEnclosure is a general-purpose class that is intended to house various types of spatial equipment found in a water system. Underground enclosures allow access to and provide protection for facilities and equipment in the water system. The contained equipment does not participate in the network—its relationship to the underground equipment is through peer-to-peer associations. The types of underground enclosures are MeterBox, ValveVault, and Vault.

ClearWell. A ClearWell is an enclosed tank that is associated with a treatment plant. Clear wells are used to store filtered water of sufficient capacity to prevent the need to vary the filtration rate with variations in demand. Clear wells are also used to provide chlorine contact time for disinfection. Pumps are used to move the water from the clear well to the treatment plant or to a distribution system.

ControlValve. ControlValves are a set of valves that operate in special ways. There are three fundamental types of control valves: backflow control, air control, and altitude. A backflow control valve is designed to prevent water from flowing in the reverse direction. Essentially, backflow control valves allow flow in only one direction—the normal flow direction. Backflow control valves are open in the direction of normal flow and closed with the reversal of flow. Backflow control valves are commonly found near pump stations and reservoirs. Air control valves are used to relieve the system of either trapped air or vacuums that may develop. Finally, an altitude valve controls water flow into a tower when the water level drops below a certain threshold. Altitude valves automatically shut off water flow when the water level in an elevated tank (or tower) reaches a preset elevation.

Types of control valves represented include AirGap, AirControl, AirRelease, Altitude, BackflowControl, Combination, AtmosphericVacuum, DoubleCheck, PressureVacuum, ReducedPressureBackflow, RPZ, SimpleCheck, Vacuum, VacuumBreaker, and VacuumRelease.

Fitting. The fitting class represents the facility found at the joint between two lines where a transition of some sort must occur. In order to cut down on the number of network feature classes and improve geometric network performance, it was decided to rely on subtypes here to differentiate the different types of fitting-related classes. Fitting types include Bend, Cap, Cross, Coupling, ExpansionJoint, Offset, Reducer, Riser, Saddle, Sleeve, Tap, Tee, Wye, and Weld.

GravityMain. A GravityMain is a type of main line that is unpressurized and relies on gravity to move the water through the main. It is a concrete class. For the water distribution model, the types of gravity mains are Carrier, InlineStorage, and TransportPipe.

Hydrant. Hydrants are installed throughout a water distribution system to give fire fighters a connection to large volumes of water. Hydrants also have secondary uses, such as flushing main lines and laterals, filling tank trucks, and providing a temporary water source for construction jobs.

Manhole. A manhole is a facility that is used to allow access to water lines and valves.

Meter. Meters are typically used to measure a customer's water consumption (volume). GWA also uses meters to measure the production from each of its wells. A meter serves as a junction on the active network. Meters are also much like hydrants in that they also have an associated warehouse object, namely, a WarehouseMeter. Typical water meter types in the GWA system are listed in Table 9-4, Typical Water Meter Types.

Table 9-4 – Typical Water Meter Types

Type of Meter	Features	Typical Uses
Positive Displacement Meter	Permanently sealed register with measuring chamber	Domestic cold water and small commercial applications with low water usage.
Compound Meter	Two meters, one large meter and one small meter with special switch over valve.	Used for services with a wide range of flows.
Detector Check	Check valve on main line with metered bypass line for low flow uses.	Commercial fire lines or any water supply system to detect leakage or unauthorized use.

PressureMain. A PressureMain is a pipeline that is designed to carry water under pressure. For the water distribution model, the types of PressureMains are defined by the subtypes: Blowoff, Bypass, AirRelease, ChemicalInjection, DistributionMain, Interconnect, pipeBridge, SamplingStation, TransmissionMain, and Unknown.

NetworkStructure. NetworkStructures are used for a variety of purposes in a water distribution system. These purposes include equalizing supply and demand, increasing operating convenience, leveling out pumping requirements, minimizing power costs, providing water in the event of pump or supply failure, and providing large quantities of water for fighting fires. The primary types of water network structures are EnclosedStorageFacilities, PumpStations, TreatmentPlants, and ProductionWells.

EnclosedStorageFacilities are reservoir tanks, either elevated or on grade. The primary function is to store water for peak period demands and assist in maintaining water pressure.

PumpStations are GWA's water booster pump stations. These facilities boost water to higher elevations, which typically discharge into a reservoir.

TreatmentPlants are facilities where GWA has treatment processes for coagulation, filtration, and disinfection.

ProductionWells are the predominant potable water sources in the GWA system. These wells draw potable water from the aquifer, with chlorination as the only treatment prior to distribution.

WaterStructure. Water structures are used primarily as the main supply centers in the water distribution network. The primary subtypes are EnclosedStorageFacility, ProductionWell, PumpStation, StorageBasin, and TreatmentPlant. GWA's facilities are stored in the NetworkStructure feature class.

Pump. A pump moves, compresses, or alters the pressure of a fluid, such as water or air, being conveyed through a natural or artificial channel. Pumps are also much like hydrants and meters as they also have an associated warehouse object (WarehousePump). Pump types include Axial Flow, Centrifugal, Jet, Reciprocating, Rotary, Screw, and Turbine.

SamplingStation. A sampling station is a facility that is used for collecting water samples. Sampling stations may be dedicated sampling devices, or they may be other devices of the system where a sample may be obtained.

SystemValve. A system valve is fitted to a pipeline or orifice in which the closure member is either rotated or moved transversely or longitudinally in the waterway to control or stop

the flow. System valves are used to regulate pressure, isolate, throttle flow, prevent backflow, and relieve pressure.

System valve types include gate, plug, ball, cone, butterfly, pressure reducing, and pressure sustaining. These specific types may be classified as isolation valves. They are designed to start and stop the flow of water within the distribution network (and isolate portions of the network for maintenance or repair).

Isolation valves are the predominant type of SystemValve installed in a distribution network. They are commonly intended to be either fully open or fully closed. They are not intended to throttle flow by being partially open.

9.8   Digitizing and Data Entry into Geodatabases

The digitizing of data and its entry into the geodatabases was enhanced by use of an ArcGIS extension called MX-Edit. MX-Edit was developed by IISGIS, Incorporated, to provide an advanced and customizable interface for organizing attribute edit forms within ArcMap to support the user's style of editing and workflow.

The major benefits of the MX-Edit extension are:

- <u>User Customizable Edit Forms.</u> MX-Edit enables the user to take control of the edit interface customized layouts, ordering of fields, and overall look of the attribute edit forms. These forms are created "on-the-fly" using saved edit session settings tied to GIS datasets.

- <u>Improved User Interfaces.</u> Many of the commonly used tools for feature selection and attribute editing are improved and organized for efficiency. This reduces the number of mouse clicks required for tools that are most often used during editing.

- <u>Custom Plug-ins.</u> Custom plug-ins were developed that can be executed automatically at edit time from the database, feature class, or down to the feature attribute level.

The SIMS Plug-in enhances the MX-Edit sewer editing capabilities by allowing functions and other operations to be available at edit time or as an add-on application. The two types of components, which make up the plug-in, are the Edit Time and the Add-On components. The Edit Time component is activated during edit time, usually unseen by the editor, and offers functions to the editor to make editing data easier and more efficient. The Add-On component offers customized applications that an editor needs to ensure data integrity, and it also provides tools that will help in data processing or in other areas pertaining to the geodatabase as a whole.

The Water Information Management System (WIMS) plug-in is similar to the SIMS editing routines. WIMS provides automated routines specific to water-related GIS features. As attributes are updated, some fields are automatically updated, thereby making the data entry faster and more reliable.

Prototype geodatabases for the water and wastewater systems were used to evaluate data sources and establish procedures for data input. As-builts and record drawings were ultimately determined to be the best source of information. Other sources were used to help fill in some gaps and resolve some conflicts.

9.8.1   Prototype Geodatabases

The data sources were evaluated and input methods were analyzed during the creation of a prototype geodatabase. This was used to help determine the best source and method of

input before embarking on the water and wastewater data collection. Agat village was used as the prototype for entering water system and sewer information into the geodatabase.

The best source of data was GWA's collection of "as-built" maps, even though it was incomplete. Discussions with various staff members indicated the as-built record is incomplete for various reasons, including damage during past typhoons and map losses during past GWA moves between different facilities.

In a previous master plan project conducted in 1993, some water and wastewater data were collected and stored in GIS shapefiles. These data were outdated in many places and did not include the entire attribute data needed for populating the geodatabase.

Additional water and wastewater system information was obtained from an annotated map set that used 1968 U.S. Geological Survey maps as a base map (the so called "USGS Maps"). The USGS Maps cover Guam with 70 maps at a 1-inch equals 400-foot scale.

In populated areas, the USGS Maps had been annotated with parcels, valves, fire hydrants, water lines, water booster pump stations, wells, reservoirs, sewer manholes, sewers, force mains, pump stations, treatment plants, and outfalls by GWA staff. The source of the data shown on the maps was assumed to be as-built drawings.

For the water system, the USGS Maps included pipe diameters, reservoir floor and overflow elevation, and reservoir capacity. These maps did not have information regarding pipe elevation, valve types, well and pump capacities, pipe material or year of construction. The USGS Maps assisted in resolving conflicts in water pipe configuration, pipe diameter conflicts, and facility location.

For the wastewater system, the USGS Maps included flow direction and pipe diameter. These maps were missing critical information such as invert elevation, pipe material or year of construction. Like the water system, the USGS Maps helped resolve conflicts in wastewater system information.

Another source of additional water system information were two large water system schematic drawings from GEPA. The water system schematic drawings showed water lines with diameters 8 inches and greater with single-line representation of the roadways. These drawings also depicted locations of wells, PRVs, reservoirs, water booster pump stations, and sampling points. The water system schematic drawings were used to help identify where PRVs may be located and resolve pipe diameter and configuration conflicts.

9.8.2   Procedures Used to Digitize As-Builts and Record Drawings

In order to meet deadlines negotiated with EPA, four water geodatabases and nine wastewater geodatabases were created to increase the rate of digitizing and data entry. This exercise expedited the data entry, but simultaneously increased the amount of weekly data review and confirmation required. Once all the as-builts and record drawings were digitized, the water and wastewater geodatabases were merged to create one water geodatabase and one wastewater geodatabase.

The as-builts and record drawings were the best source of information for the geodatabases. Features and attributes on these drawings were digitized into the geodatabases using Mx-Edit and the appropriate plug-in. An as-built drawing checklist was created to ensure that each set of drawings in the GWA map room was digitized. Upon completion of the digitizing of the as-builts and record drawings, there were significant areas with little or no

information on the water or wastewater system. These areas will ultimately require additional investigation by GWA to progressively increase the level of geodatabase accuracy, a common need during the long-term development of geodatabases for utilities..

The water and wastewater assets were digitized by following these general steps:

- Analyzed the plans and determine the location of the asset.

- If the location was not recognizable, determined the location using the grid coordinates on the plan.
  - If the grid coordinates were in the GGTN 1963, converted the coordinates to the Guam Geodetic Network of 1993 (GGN1993), using the conversion tools available.
  - Entered the grid coordinates onto the electronic map to determine the exact location of the pipe.

- Once the location was determined, digitized the length of the pipe onto the electronic map. Digitized the pipe in relation to which side of the road it should be on.

- After digitizing the pipe onto the electronic map, populated the fields in the geodatabase associated with the pipe. Filled in as much information as the plan contained. If no information was available for certain columns, used the "unknown" option to populate the column. Continued digitizing and populating the databases for the set of plans.

- Saved all work every five minutes to ensure no loss of data.

9.8.3 Quality Control Processes

Mx-Edit has programmed routines to validate critical data fields when needed. Other data queries were performed manually to ensure data quality. For example, a query was run on the Asset_id Field to ensure that each feature had a unique number to identify it. More complex checks, such as tracing routines, were more difficult due to data being entered into multiple geodatabases. A more thorough evaluation of the data was required prior to merging the geodatabases.

9.8.4 Data Completeness

The precise level of completeness for the geodatabase is difficult to determine. Data was only entered into the database using as-built or record drawings. Other data (such as the USGS Maps noted above) were used to help resolve conflicts between different sets of "as-built" drawings and fill in the gaps needed to properly construct the water and wastewater hydraulic models. However, those data were not entered into the geodatabase because of concern that it would be difficult in the future to distinguish between more reliable information from construction drawings and less reliable data from schematics and larger scale single-line drawings.

Based on a comparison of the hydraulic model pipe data and the GIS pipe data for the water and wastewater systems, some approximations of data completeness can be made. For the water system, the GIS database has about 15% less pipe length than model in sizes 6 inch and greater indicating the level of missing data from as-builts. Based on the current GIS

data, there is a total of about 400 miles of pipe in the geodatabase and 15 miles for pipes 4 inches and smaller. The greatest discrepancy between what exists in the field and the geodatabase data is in the pipes 4 inches and smaller. The principal reason is the lack of as-built information for the smaller pipe sizes.

For the wastewater system, the difference between the GIS database pipe length and model pipe length in the modeled sizes (10 inch and greater) is about 10 percent. Based on the current GIS data, there is a total of about 320 miles of sewer pipe in the geodatabase and about 200 miles for pipes 8 inches and smaller.

The current water and wastewater geodatabases represents an excellent first step in the long term process that is needed to develop and refine the utility databases. This conclusion is especially true given the completeness of GWA's as-built and record information. GWA will need to hire qualified GIS staff to oversee the ongoing refinement that of the geodatabase and realize its full potential.

9.9   GIS Program Recommendations

GWA's GIS program is still in its first stage of development. Further development of the GIS will depend on the following actions:

- Hiring a GIS Administrator
- Hiring at least one GIS Analyst
- Acquiring additional software and computer hardware
- Establishing a workflow to support GWA
- Using consultant services to complement GWA's own staff efforts

The following sections outline the recommendations for continuing GWA's GIS program.

9.9.1   Staffing Recommendations

GWA should hire new staff members committed to developing and improving its GIS program. Two key positions needed are a GIS Administrator and a GIS Analyst. GIS Technicians should be hired as needed to support the Analyst and Administrator.

The GIS Administrator facilitates the development, creation, manipulation, production, implementation, and administration of the water and wastewater GIS systems. The ideal GIS Administrator should have extensive experience in and knowledge of:

- Administrative principles and practices, including program management and supervision of employees
- Principles of budget development and administration
- Geographic information systems, applications, and analysis
- Spatial data formats, projections, datums, and conversion techniques
- ESRI ArcGIS, ArcInfo, ArcView, Spatial Analyst, 3D Analyst, and other extensions
- Water and wastewater utility operations

- Software and computer languages such as MS Access, Visual Basic, MS Project, and Relational Databases

- Basic AutoCAD skills

- Desktop computers

- Local and wide area networks

Hiring a GIS Administrator should be the top priority. In turn, the GIS Administrator should be allowed to hire staff and acquire equipment based on his or her assessment of GWA's current and future GIS needs.

The GIS Analyst performs spatial analysis using geographic information software and integrated geographic data for producing complex maps. The GIS Analyst should be able to:

- Understand geographic information systems, applications and analysis.

- Understand spatial data formats, projections, datums and conversion techniques.

- Understand, at a general level, water and wastewater utility operations.

- Collect, input, edit and verify spatial data; manipulate, model and analyze spatial data in the established GIS.

- Conduct technical research in GIS to produce maps.

- Document data, procedures and analyses for use in a variety of situations.

- Implement (and possibly participate in developing) timesaving program enhancements that serve GWA's needs.

- Troubleshoot and perform maintenance on GIS hardware and software problems that require consideration of alternative solutions and resources.

GIS Technicians should also be hired as needed to support the GWA Administrator. Persons who qualify for the GIS Technician should have one to two years of experience with the following tasks:

- Using ESRI's ArcGIS tools to input edit data, and to prepare and produce various maps, related geographic database information and other GIS tools and products.

- Assisting GIS staff in the generation of plots, analysis of data, development of new data, distribution of GIS data and products, collection of data with Global Positioning System (GPS) units and editing spatial data.

- Assisting in developing geographic database structure, tables, forms and reports; producing maps and graphics as needed; and providing quality control for GIS deliverables.

9.9.2   Software Recommendations

GWA's GIS program will require additional software to support the growth of the program. It is recommended that GWA add the following software to complement the two ArcInfo licenses it currently owns:

- Two ArcView licenses
- Two ArcEditor licenses
- ArcSDE
- SQL Server

ArcView allows users to view, query, and analyze geographic data. ArcView will be provided for end users such as GWA's administration, laboratory, engineering, or field operations groups.

ArcEditor includes all the functionality of ArcView and adds the capability to create and edit data in a geodatabase. ArcEditor is intended for GIS Technicians to create and edit data in a geodatabase.

ArcInfo software has all the functions of ArcEditor, but it allows the management and administration of a geodatabase. Some of the additional functions include creating new feature classes and adding new domains that GWA may need.

ArcSDE is an application server that facilitates storing and managing spatial data in either Microsoft SQL Server, Oracle, IBM Informix Dynamic Server or IBM DB2 Universal Database relational database management systems (RDBMS). Multiple sessions of viewing and editing the data are managed through ArcSDE. ArcSDE will be needed to manage a shared, multiuser geodatabase in standard RDBMS systems.

In order to implement ArcSDE water and wastewater spatial data must be transferred to one of the four databases mentioned above. Microsoft's SQL Server is the recommended RDBMS to store the spatial data. Microsoft SQL Server is a database platform that supports spatial information storage and application implementation. All the spatial data access and editing will be managed with ArcSDE.

Table 9-5 summarizes the software needed and their budgetary costs.

Table 9-5 – Summary of Software and Costs

Software	Qty	Budgetary Cost ($)	Total Budgetary Costs ($)
ArcView	2	$1,500	$3,000
ArcEditor	2	$4,000	$8,000
ArcSDE	1	$10,000	$10,000
Microsoft SQL Server	1	$22,000	$22,000
		Cost Total	$43,000

The software costs do not include the annual maintenance fees that ESRI charges for its software. The fee provides technical support and all software updates for the year.

9.9.3   Hardware Recommendations

GWA's GIS staff will need computers designed to perform with ESRI's ArcGIS family of products. Desktop systems having the following minimum hardware configuration are recommended:

- Dual-Core processors (Intel Core 2 Duo or Athlon 64 X2)
- 2 GB of system RAM
- Video card (graphics adapter) with 256 MB GDDR3 video RAM
- 100 GB 7200 rpm hard drive
- Dual layer DVD ±R/±RW drive
- 2 USB 2.0 ports
- Network interface card
- Windows XP Professional Service Pack 2 operating system
- 19-inch LCD monitor

The computers described above are based on computers that ESRI bundles with ArcGIS software.

A large format color plotter is required for plotting large format maps. The large format plotter should be able to plot approximately two D-size sheets per minute.

A large format scanner is recommended for scanning in maps, design drawings, and other maps that GWA could use for supplementing its water and wastewater data. The large format scanner should be able to:

- Scan color at a minimum of 3 inches per second.
- Scan black and white at a minimum 10 inches per second.

The minimum speeds specified above are based on a Hewlett-Packard DesignJet 4500 multi-function printer (mfp). Additional hardware upgrades, such as additional RAM or a larger in-plotter hard drive, may be needed for scanning large maps or printing detailed maps.

Table 9-6 summarizes the hardware needed and their budgetary costs.

Table 9-6 – Summary of Hardware and Costs

Software	Qty	Budgetary Cost ($)	Total Budgetary Costs ($)
ArcView/ArcEditor/ArcInfo Workstations	5	$3,000	$15,000
ArcSDE/MS SQL Server	1	$10,000	$10,000
Large format scanner/plotter	1	$35,000	$35,000
		Cost Total	$60,000

9.9.4   Workflow

Updating and editing the water and wastewater geodatabases will be an ongoing challenge. Implementing a workflow to manage the data that are added and updated in the

geodatabases will be key to improving the quality of the data collected. Figure 9-3, New Data Workflow shows a recommended workflow for new and updated data.

As new information arrives in the form of construction drawings or field-collected GPS data, GIS Technicians should review and enter the new data using ArcEditor. New and edited data are held for review and approval by the GIS Administrator. Once the data are approved, they are entered into the geodatabase.

In addition to the new and updated data workflow, daily data viewing and analysis will occur. These tasks will require use of ArcView to access and analyze the data for work such as work order maps, plotting of laboratory monitoring data, and utility checks prior to construction. The geodatabases can be simultaneously viewed, analyzed, edited, and updated through ArcSDE's administrative tools.

9.9.5   CIP Projects

GWA's geodatabase will need field investigation for areas of the water and wastewater system that do not have record drawings. The initial GIS CIP uses five years of CIP projects to update and improve the data. A budget of $160,000 per year for five years will help GWA continue to improve the geodatabases and recruit personnel for the GIS program. The annual dollar amount was developed based on manageable scopes and budgets for GWA's staff. The scope of work and budget for each year is based on:

- Wastewater and water lines are readily accessible
- 3-man crews for field investigation
- Locating approximately 300 sewer manholes per year
- Non-entry manhole measurements of invert and influent and effluent sewer diameters
- Adjacent water lines in vicinity of the sewers are located

GWA should review the geodatabases in its entirety to assess the critical data needs for each year's GIS CIP effort. The five-year duration is not intended to mark the end of GWA's GIS geodatabase development, but an opportunity to assess the GIS program as a whole and address:

- Staffing
- Data
- Computer hardware and software
- Future budgets

The scope and budget of future GIS CIP projects should increase as GWA's GIS staff and experience improves.

Figure 9-4 – New Data Workflow