Multi Purpose Stormwater Facility Mapping in San Diego County

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Abstract

The County Department of Public Works is continuing an on-going project of mapping stormwater facilities. These facilities include lined and unlined channels operated by road and flood control divisions, and pipes operated by road and flood control divisions. Mapping has included field inventory, mapping of route events, mapping from development plans and GPS mapping in the field. Mapping has been done by both DPW staff and by a consultant.

Inventory and mapping serve multiple purposes, including maintenance, GASB 34 compliance, regional water quality permit compliance, and drainage master planning.

Software used has included Access, Trimble Pathfinder and Terrasync, Arcview, ArcGIS, and ArcInfo. Future transfer of the data to Hanson Systems software is being explored.

Introduction

MS4 is an acronym for "Municipal Separate Storm Sewer System," meaning a system intended to convey stormwater runoff only, separate from sanitary sewage. This distinguishes the system from combined sewer systems where sanitary sewage, containing human waste, is mixed with storm runoff.

San Diego County is mapping its MS4 facilities for several reasons:

1. Mapping is a requirement of the National Pollution Discharge Elimination System (NPDES) permit issued by the Regional Water Quality Control Board, pursuant to California's implementation of the Clean Water Act. In San Diego County, all local governments (18 incorporated cities plus the County) and the San Diego Unified Port District are considered "co-permittees" for the permit. The permit, issued February 21, 2001, includes the condition that co-permittees produce an "accurate map" of each watershed draining to the Pacific Ocean, including among other things, MS4 facilities.

2. The General Accounting Standards Board (GASB) standards for local government indicate that local governments should maintain an inventory and valuation of all assets owned and that, where appropriate, such assets should be capitalized and included in balance sheets.

3. The County Department of Public Works needs an accurate inventory showing locations and connections for their own maintenance activities.

4. The County prepares Drainage Master Plans for selected areas from time to time. Mapping of MS4 facilities provides a useful resource for the inventory phase of these studies.

Planning Process and Project Status

In 2002, many meetings were held about the definition of MS4 and plan of attack for the project. There was extensive debate about what should count as an MS4 facility; e.g. should brow ditches count? (No.) Should isolated culverts that simply convey water from one side of the road to the other count? (At first "no" but later revised to "yes".) And so on. Some DPW managers expressed concern that the County not inadvertently acquire responsibility for maintaining natural waterways or private facilities.

The most important activity of the planning committee was to identify existing inventories and gaps in inventory. The inventories that were found were 1) Flood Control Channels, listed in an Excel spreadsheet, 2) Flood Control Pipes, highlighted on a set of subdivision plans and bound in books, 3) Road Fund channels (actually an inventory of RGP53 channels; see below for explanation of RGP53) listed in an Excel spreadsheet, and 4) Road Fund Culverts, listed in a Microsoft Access Database. Note that the Road Fund and Flood Control District are separate sources of funding for construction and maintenance, hence two inventories of culverts and two inventories of channels. While they may be physically the same, County usage has deemed Flood Control culverts as “pipes” and the term “culvert” has been applied to Road Fund culverts.

During 2002, the above inventories were mapped, with culvert inlets geocoded as points, and the other features (Channels and Pipes) digitized as lines. At present, in 2005, a Phase II mapping is underway, using GPS to map culverts as lines.

The First Culvert Inventory

The first culvert inventory was accomplished five years ago using interns, with the data stored in a Microsoft Access Database. Approximately 14,000 culverts were inventoried. Culvert locations were described by distance along a road centerline at a measured distance from a crossroad or other landmark. While the method is viable, two mistakes were made in the first iteration. First, the work of the interns was not closely enough supervised, and that resulted in some roads being skipped and, simultaneously, some culverts being inventoried more than once. In some cases, redundant culverts were not easy to recognize, if one intern inventoried the road in one direction and another in the other direction. Such redundancy came to light only later, when culvert were mapped. Second, road names, crossroads and survey direction were not standardized. The County already had a “road register” system which systematically inventoried all County roads and standardized naming and segmentation. The stormwater field crews were not aware of that pre-existing system. Had they been aware of it and used it, the culvert inventory could have been done more accurately from the outset.

Because the interns had produced a somewhat flawed work product, the inventory was subsequently cleaned up and modified by full time staff. Roads that had no culverts were included in the inventory with one dummy culvert record with a culvert type of “none.” The direction of survey was standardized, although the road names and crossroad names were not.

A typical description of culvert location would include

Roadname, distance, direction, crossroad_name

e.g.

“CALAVO RD”,”85”,”N”,”STAGE COACH LN”

The location description applied to the INLET of the culvert. Further description included the nature of the routing, e.g. “STE” indicates that the culvert crossed the road, “PAR” indicates that it runs parallel, “PVT” indicates that it connects to a privately owned pipe, and so on.

Culvert Mapping Phase I

In the first version of mapping for MS4 the culvert inventory was mapped as point events on routes. Each road name/crossroad (or landmark) combination started a new route, and the route was custom built. Mapping of culvert inlets was nearly 90% successful, but a number of problems surfaced. Non-standard street names resulted in non-matches. For example, non-standard abbreviations for street name extensions were common; the standard abbreviation for Boulevard is “BL”, not “BLVD.” Even using standard extensions, “RD” is easy to substitute for “DR”, and so on. Road name aliases also produced a share of confusion; for example State Route 94 is also known as Campo Rd.

Cul de sac street centerlines are mapped to the center of the cul de sac. Culverts are often at the end of the cul de sac, so the measured distance to the culvert exceeds the length of the street. This required that many cul de sac streets be extended in order for the event mapping to succeed.

Figure 1. Culvert Inlet Locations Geocoded on Road Centerlines
Red triangles indicate the geocoded position of culvert inlets.

Other Mapping Activities in 2002

In addition to the culvert inventory, two inventories of channels were also mapped. These were lists maintained in Microsoft Excel files. The two lists were

Flood Control Channels – these were open channels whether lined or not, that were not within road right of ways, and therefore owned and operated by the Flood Control District. This list included 115 flood control channels. Some of these channels were of considerable length, with the longest exceeding a mile in length.

RGP53 Channels – this list provided the location of channels within the road right of ways.

RGP53 is a program of the Division of Fish and Wildlife, which issues permits for cleaning of watercourses. RGP53, allows a blanket permit for cleaning of all of the facilities on the list, avoiding the lost time and expense to the County of applying for each individual cleaning site, and likewise, saving DFW the expense of handling all of the permits individually. This list included 900 road fund channels.

Both types of channels had locations described along roads, but the distances were expressed in tenths of a mile, which was too course to be useful for mapping. County flood control field crew were recruited to map these channels using GPS units. Following training sessions, the field crews provided points labeled “START”, “END”, and “TURN” as needed. Field crew and GIS staff then sat together with GPS points overlaid on an aerial photo in ArcView 3.2 to draw the channels as linear features.

There were also numerous pipes maintained by the Flood Control District. The Flood Control field supervisor had assembled a collection of recorded maps over the years, with the map pages showing the location of flood control pipes bound in a series of books. These books were provided to a consultant/contractor (Rick Engineering) for digitizing. The consultant digitized some 4410 pipes and 4884 structures (BOX, HEADWALL, etc.).

Culvert Mapping Phase II

While mapping point locations of culvert inlets on road centerlines is useful, mapping of culverts as lines is far better. Accurately mapped lines show the true locations of inlets and outlets, plus direction of flow and connections of culvert to culvert, culvert to channel and so on. For this phase of mapping, our general approach is to collect inlet and outlet locations by GPS and connect the dots with lines.

Road maintenance, including culvert maintenance, is organized by 12 “roadstation” areas. Roadstation areas average about 1400 culverts each. Field crews work within a single roadstation area at a time, making their way alphabetically through a list of roads that have inventoried culverts. The alphabetical approach causes some excess miles to be driven in data collection, but the field crews are confident and comfortable with an orderly approach.

To collect the location of a culvert, the GPS operator stands on the inlet, or as near a possible, and initiates point collection. Only one attribute field is collected; it is named “comment.” For the inlet of culvert 8541, the comment would be “inlet 8541.” After ensuring that enough GPS positions have been averaged – say 5, at one per second, the point collection is completed. The operator then moves to the outlet of the culvert, and repeats the process, with the comment being “outlet 8541.”

If the inlet of a culvert is the outlet of one or more other culverts, the comment might look like this: “inlet 8633, outlet 8631, 8632.” Other variations are possible; for example, if reaching the actual outlet of a culvert would require climbing down an unreasonably steep bank, the operator might estimate the distance and enter “outlet 8819 +15ft.” By agreement, we have established that this notation means that the outlet is 15ft beyond the GPS point, in the direction established by the 2 points.

GPS points collected in one day are post-processed the next work morning to achieve submeter accuracy. The corrected file is then exported to an ESRI shapefile of points.

Figure 2. GPS Points at Inlets and Outlets.
Note that the geocoded point on Capri Ct is spurious; there is no culvert on Capri Ct. Also note that Darlington Ct and Elva St were GPSd on different days, resulting in two GPS points near the intersection of Darlington and Elva.

GPS Equipment

In 2002, we used a Sokia Axis3 backpack unit with a real time correction via satellite. The real time correction requires a paid subscription. The field crews doing the GPS collection for this phase did not like the backpack unit due to it having multiple parts, and they requested a single piece unit. The Trimble GeoXT was chosen for the purpose. The GeoXT is less expensive to purchase than the Sokia, and does not require the additional on going cost of an annual subscription. The tradeoff is that the rover data has to be post-processed to achieve the claimed sub-meter accuracy.

From time to time, satellite configuration or space weather will interfere with data collection. The Sokia, in real time, will refuse to collect data. The Trimble will collect data, but the data sometimes later fails to correct. Both units appear to deliver their claimed accuracy, and, in general, our experience has been satisfactory.

With the Trimble units, the rover file (.ssf file) is transferred from the field data collector to a laptop or desktop computer. In the computer, Trimble Pathfinder software is used to post-process the rover file to produce a corrected file (.cor file). The same Pathfinder software is then used to export the corrected file to an ESRI shapefile containing points.

Mapping the GPS Data

The main data product we want is a GIS file of lines, with appropriate descriptive attributes attached.

To produce the desired file, we work in ArcMap (ArcEditor), add a file of exported GPS points to the map and start editing the culvert line (culv_lines.shp) file. Because the data collection has been kept simple, it is an easy matter to draw a line collecting and inlet to an outlet. Lines are drawn in the direction of flow, and symbolized with an arrowhead to display the flow direction. Snapping is turned on most of the time, so that connecting culverts are sure to actually connect.

Figure 3. Lines Drawn to Connect the GPS Points
Compare the information in this image to Figure 1. The lines show actual locations, connectivity, and direction of flow, a far richer information environment than simple points on the road centerline abreast of inlets.

One matter that took some discussion to resolve was representing “Tee” intersections. Some culverts join larger and longer culverts without the existence of a structure. The field crew wanted the long culvert to be a single line. Because of experience editing GIS data with ArcInfo coverages, GIS staff was predisposed to require a node where the lines joined. The field crew argued that the long culvert was physically one pipe, and it had a single number and line of data in the culvert inventory, and besides, there really was no structure present. So a single line it is. ArcMap allows snapping to an “edge” – in this case the line, so representing the “Tee” is easy, and subsequent network building is successful.

The culv_lines.shp file contains few attributes. The [shape] attribute is inherent. There are also attributes for notes, length, ownership, and the ID. All other data about the culvert is made accessible by joining the culvert table from the culvert database (in Microsoft Access) using the ID as a common field. The ID is, in fact, the internal Access ID that is assigned by Access. This number has been "locked down" in the Access database to ensure that it does not change when records are deleted or inserted. Using this ID in this way is probably not the best practice, but it was an expedient measure taken in 2002, since there was no other unique ID available. It will eventually be replaced by a unique asset number, but will be used for the remainder of this mapping phase of the project.

The joined data in the culvert inventory include material, diameter, type of inlet, type of outlet, depth of cover, condition, last inspection, last maintenance, confined space status, and much more. This information does not need to be maintained in the GIS system, since attributes changed in the Access database will automatically be visible in the joined data.

Mapping Structures

We wanted to produce a shape file of points showing structures such as cleanouts, boxes, headwalls, and so on. For this purpose, Workstation ArcInfo was used. The culvert line shape file was to a line coverage, the nodes were built, and an aml written to extract the type of inlet and outlet, and assign the appropriate value to each node. If a node is both inlet and outlet, the culvert for which it is an inlet is allowed to assign the inlet type to the node. At the end of this process, nodes were converted to a shape file of points.

Mapping Fictitious Lines

An additional shape file was created and named "fictitious.shp." The name has caused some confusion, but the there are several uses of fictitious lines. Broadly speaking, there are two motives for using fictitious lines; first to simply indicate the existence and location of certain facilities, even though they are not County owned, and, second, to enable the completion of a flow network in the future.

Fictitious lines are used to represent a known structure or pipe that is not a County facility. For example, when the California Department of Transportation (CALTRANS) built a new section of State Route 125 (SR 125), it installed a large box culvert within the right of way. That large culvert is represented by a "fictitious" line, and we are able to represent the drainage of numerous County culverts to that line, when they would otherwise appear to dead end.

In some cases it is clear that a pipe, in private ownership, has to exist. Pipes that are completely private are not inventoried in the culvert database, so the existence of the pipe is indicated as a fictitious line.

Fictitious lines are used to join a culvert to channel centerlines where the channel may be wide, and it is desired to represent the culvert at its true length. Rather than exaggerate the length of the culvert, a fictitious line is used to connect the end of the culvert to the centerline of the channel.

Fictitious lines may also represent any other flow lines to complete network between the inventoried culverts and blue line streams.

Figure 3. Use of Fictitious Lines to Complete Drainage Network
The heavy cyan lines are Flood Control channels; the thinner magenta lines are Road Fund culverts. The dashed black line represents a known underground structure whose ownership has not yet been researched. The fictitious line completes the network by connecting the open Flood Control Channels. There are also, barely visible in this image, three short fictitious lines from the ends of culvert to the centerline of the channel.

Distribution and Use of Maps

As the pilot phase of line mapping was underway and complete, we sought a way to distribute maps to users. The County has prepared two ArcIMS applications to provide web-based GIS information to various internal staff users of data, such as permit processing and code enforcement staff. Presumably, when the MS4 mapping project is complete, an existing or new ArcIMS application could be used to make the data available. The IMS application administrators prefer not to begin this while the mapping work is still in progress.

In the meantime, a couple of low cost/low effort options have been used.

First, field crews wanted paper maps. Experimentation with several formats and scales was interesting. Ultimately, for readability, everyone agreed that 100 ft/inch was greatly preferred over any smaller scale (like 400 ft/inch). Also, field crews want maps that are not too unwieldy in a truck cab in the field. They eventually asked for each map to cover a single Thomas Brothers grid cell (e.g. page 1275 - C3). County staff are quite familiar and comfortable with Thomas Guide maps and the grid system is well known. The drawback is that this produces a large number of maps (over 300, for the pilot area alone).

Production of the maps was accomplished by downloading a free MapBook extension to ArcMap 8 from the ESRI website. The Thomas grid cells in the pilot area were made into the index map, and the mapbook printed and bound. The MapBook extension can also be made to produce PDF maps in place of paper maps, and a set of PDF maps was placed on a common drive on the County computer network, for use by interested staff. While the PDF files do not offer full GIS functionality, they allow users to zoom in and out, and to search for street names and culvert numbers. Using the PDFs is faster than using the paper maps. The paper maps are being used for review, and marked up.

Future Steps

The County is undertaking a conversion of its asset inventories to the Hanson system. When the culvert mapping project is complete, the tabular inventory will be transferred from Access to Hanson. Hanson offers extensive reporting, work order generation and integration of time reporting and cost accounting tied to specific assets.

A future mapping phase is expected to tie MS4 mapping and maps of natural waterways into a single network showing drainage from the Pacific/Colorado divide to the Pacific Ocean, with the ability to trace flows either upstream or downstream from a given point. While the scope of this phase does not include building the network, a small area was mapped as a pilot project and proof of concept. ArcGIS 8 was used for the test, and was found to successfully combine lines from multiple layers (channels, culverts, fictitious lines, and blueline stream reaches from the National Hydrographic Dataset) into a single network.

Once mapping is complete, the information will be made available to enterprise GIS users. The data will be provided to SANGIS to be available via SDE. In addition, many internal users of GIS data are currently served by two internal ArcIMS applications. ArcIMS applications allow users to view GIS data with only a web browser. MS4 features will be added to one or both of these applications.

There is also a desire to convert field staff from using paper maps to using an electronic solution running on a laptop or tablet PC. This would reduce the time, effort and expense of producing paper maps, and provide data that is known to be current. Electronic capture of updated descriptive attributes in the field is also desired, to replace the current process of updating paper forms and having a separate data entry step with attendant delays and errors.

Conclusion

The County has elected to undertake MS4 mapping with its own staff rather than a consultant. The perceived advantages include high motivation to produce a quality product, existing staff's familiarity with the drainage system in their territory, continuity of efforts and methods, and retention within the County organization of expertise developed through the mapping process.

Field staff have proven competent and able to learn necessary skills in use of GPS and computer equipment and software.

The present phase of mapping culverts continues mapping work begun in 2002, and will be followed by further refinement. Ultimately, it will be possible to trace water flows up or downstream from any point in the County between the Pacific/Colorado divide and the Pacific Ocean.

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