Municipal Environmental Laboratory Report

MULTI-AGENCY

Benchmarking Study

December 1999

MULTI-AGENCY BENCHMARKING STUDY

Municipal Environmental Laboratory Report

Participating Agencies

Central Contra Costa Sanitation District
City of Los Angeles Bureau of Sanitation
City of Portland Bureau of Environmental Services
East Bay Municipal Utility District
King County Department of Natural Resources
Orange County Sanitation District
Sacramento Regional County Sanitation District
City of San Jose/Santa Clara Water Pollution Control
Massachusetts Water Resources Authority

December 1999

Data and information used to develop this report are from Fiscal Year 1997 (FY1997).

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Introduction

The management of municipal environmental laboratories has undergone significant change during the past 10 years. Laboratory managers have been faced with: increasing pressure to provide cost-effective service, higher expectations from customers, increasing regulatory requirements, and increasing complexity of work (such as lower detection limit requirements). They have had to respond by making their operations more efficient, competitive with the private sector, and responsive to their customers' needs and requirements.

To meet these challenges, a group of nine municipal government laboratories joined together in a benchmarking study of the laboratory component of the wastewater industry. Participants in this study included laboratories from the seven agencies participating in the multi-agency study (Central Contra Costa Sanitary District, East Bay Municipal Utility District, King County Department of Natural Resources, City of Los Angeles, Orange County Sanitation District, Portland Bureau of Environmental Services, and Sacramento Regional County Sanitation District), plus two additional agency labs, the City of San Jose and The Massachusetts Water Resources Authority. In addition, although the City of Phoenix participated on a limited basis in the early stages of the benchmarking process, it is committed to full participation in next round of data collection.

Goals of the laboratory benchmarking component of the multi-agency study included:

- Improving the functional operation of the participating laboratories;
- Minimizing costs and maximizing efficiencies wherever possible;
- Developing a model that could be used to compare costs for individual analyses;
- Developing a model that can be used in the future to compare changes from year to year;
- Identifying best practices of individual agency laboratories; and
- Identifying laboratory costs associated with individual components of the wastewater treatment process.

The major work products of the group included:

- Process benchmarking survey;
- Tables comparing staffing, salaries, benefits, workload, and lab organization;
- Extensive budget, cost per test and productivity comparison data;
- Input to the laboratory portion of the multi-agency template; and
- Normalized data comparing agency costs for the multi-agency template categories.

All of the agencies have participated in the first three work products, and only those in the multi-agency study have participated in the last two work products. The study period was fiscal year (FY) 1997, with the exception of King County, which reported calendar year (CY) 1997.

Agency Overviews

Central Contra Costa Sanitary Distinct

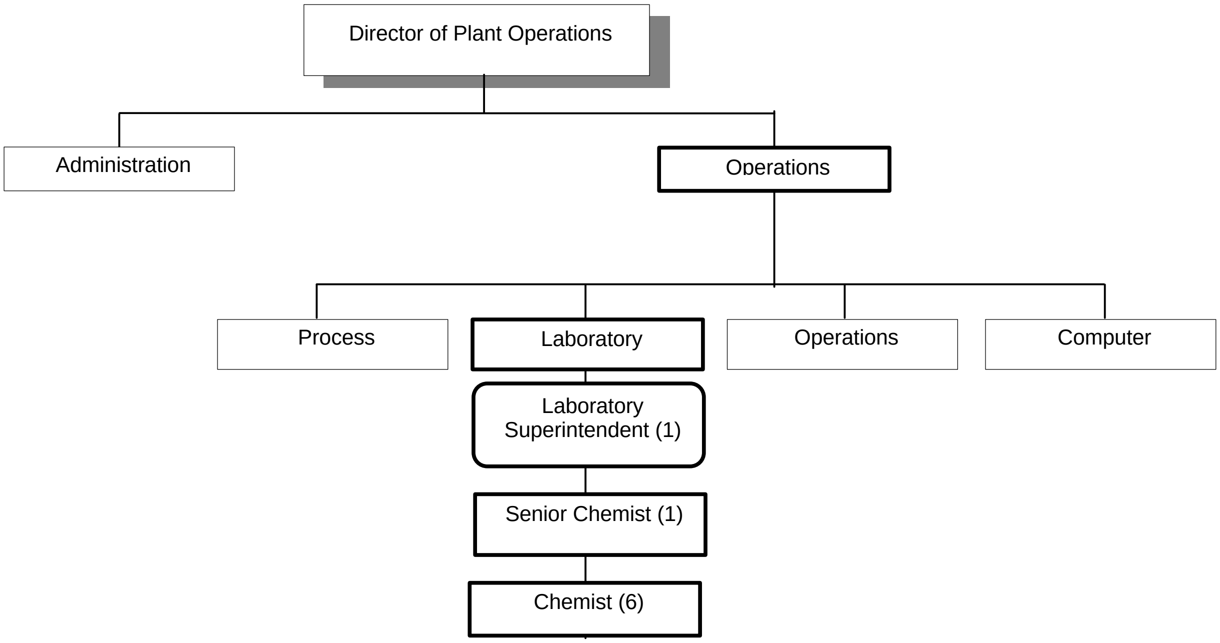
The laboratory is located on the District's wastewater treatment plant site in Martinez, California. The laboratory facility measures approximately 6,400 useable square feet, which includes a superintendent's office, a senior chemist's office, analytical testing areas (biology, conventional chemistry, metals and organics) a sample receiving area, a common preparation room, chemical storage, and office space for the chemists.

Staffing for FY1997 included a laboratory superintendent, one senior chemist, six chemists, and one co-op student. Clerical support is provided by the Administrative Section and is not included in the laboratory budget.

The laboratory is a full-service environmental testing facility that is certified by the California Department of Health and the Department of Fish and Game for various types of water and wastewater analyses. Major laboratory instrumentation includes: graphite furnace and flame AAs, GC/MS, a cold vapor mercury analyzer, HPLC, gel permeation chromatography, and an automated organic extraction and concentration system. The entire laboratory data handling is automated through the Laboratory Information Management System (LIMS).

The laboratory reports to the Plant Operations Division Manager, who reports to the Director of Plant Operations. The Director of Plant Operations oversees the maintenance and operations of the wastewater treatment plant. The laboratory has six discrete work groups that include Microbiology, Wet Chemistry, Metals, Organic Chemistry, Toxicology (Bioassay) and Quality Assurance/Quality Control (QA/QC). A Chemist II, who reports directly to the Senior Chemist, heads each group. The Senior Chemist and QA/QC Officer report directly to the Laboratory Superintendent. The following organizational chart (Figure 1) describes the staffing and reporting relationships of the laboratory:

Figure 1: Central Contra Costa Sanitary District laboratory staffing.



The workload for the CCCSD laboratory can be divided into the following areas:

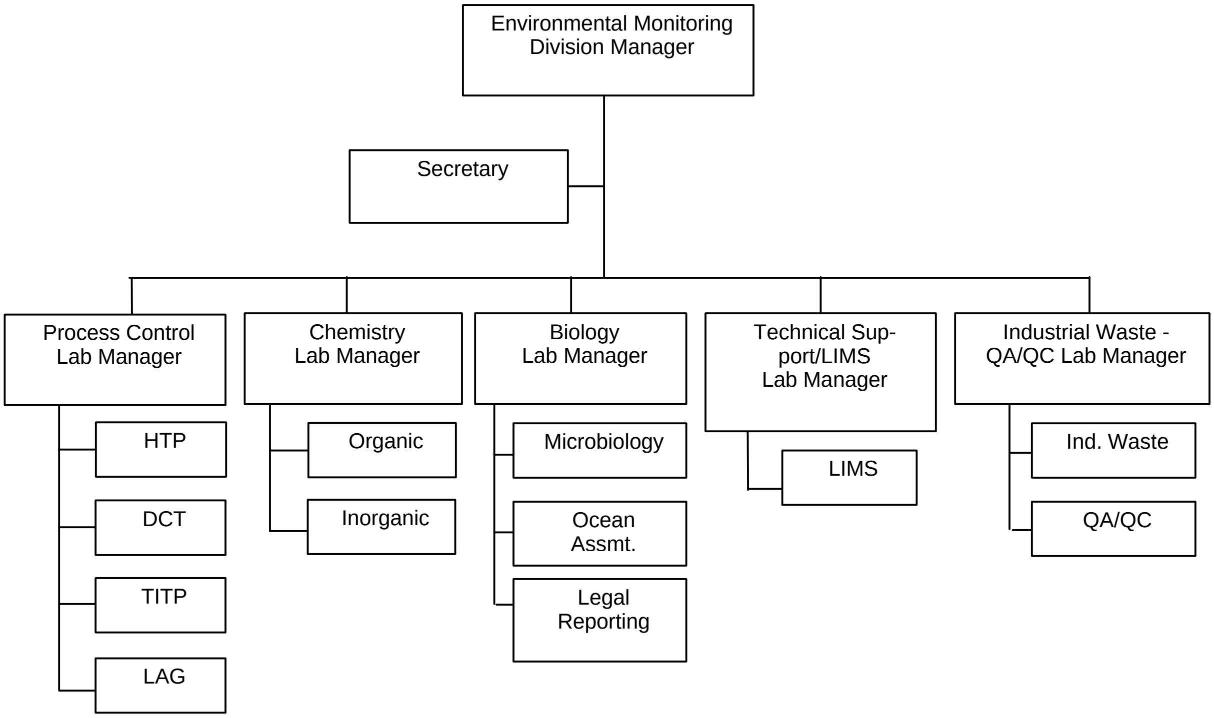
- Wastewater operations support accounts for the 72% of the overall laboratory workload. Of that amount, 20% is discretionary and 52% is related to compliance monitoring.
- Source Control, Collection System Operations and Engineering support account for approximately 8% of the overall laboratory workload.
- Supervision, LIMS, research and development, QA/QC, and safety accounts for 20% of the laboratory workload.

Approximately 9% of the FY1997 laboratory budget covered analytical costs for work subcontracted to outside laboratories.

City of Los Angeles

The Environmental Monitoring Division (EMD) of the Bureau of Sanitation, Department of Public Works, City of Los Angeles, provides quality environmental data and assessment in support of the bureau's activities. The division is organized into five sections (Biology, Chemistry, Industrial Waste, Process Control, and Technical Support) and three groups. Each section is then subdivided into one or two units, with the exception of Process Control, which has four process control laboratories located at each of the City's treatment plants. The three groups are: the QA/QC group (reporting to the Industrial Waste section manager), the LIMS group (reporting to the Technical Support section manager), and the Legal Reporting group (reporting to the assistant division manager). The organizational structure is summarized in Figure 2:

Figure 2: City of Los Angeles laboratory staffing.



The staffing level for the division in FY1997 was approximately 115, of which 104 were dedicated to wastewater activities and 11 to non-wastewater activities. The division staff consists of laboratory managers, supervisors, chemists, water biologists, water microbiologists, and laboratory technicians. The division occupies approximately 53,000 square feet of laboratory space in 10 buildings located at four treatment plants. The main laboratory is located at the Hyperion Wastewater Treatment Plant. The California Department of Health Services accredits the division's laboratories through their Environmental Laboratory Accreditation Program.

Analytical capabilities of the Environmental Monitoring Division include conventional chemistry, microbiology, aquatic toxicology, organics, metals, air testing, and marine biology. The division provides support for treatment plant processes, NPDES permit requirements, source control, landfill operations, the sewer collection system, receiving water monitoring programs, and capital improvement projects. In addition to providing analytical services, the division is also responsible for preparing plant NPDES permit reports and annual assessment reports on receiving waters, providing consultation on environmental compliance and regulatory issues, and participating in the activities of various engineering projects planning teams. Plant operators collect most samples for routine process monitoring tests. Laboratory staff usually collects grab samples, samples for special studies, ocean monitoring samples, and microbiology test samples. Less than 0.1% of the operating workload is sub-contracted to outside labs. This is primarily in areas where the limited number of samples does not make it cost effective to maintain the testing capability in-house. Testing is also subcontracted occasionally as a backup in case of sample overload or equipment breakdown.

The Environmental Monitoring Division has an annual operating budget of $9.16 million, which includes salaries, contractual services, laboratory supplies and expense, and equipment. The laboratory staff charge their time to work order numbers on timesheets, which are associated with customer projects (template categories) in both wastewater and non-wastewater operations. Expense costs are tracked at the unit level. Each unit then apportions these costs to each template category according to the total staff time spent in support of that category.

Most of the division's resources are directed in support of the wastewater program. Within the wastewater program, 73% of the laboratory work is dedicated to the fulfillment of the NPDES requirements of the four treatment plants and source control. The remaining effort of the division is used by the bureau to provide the best waste management services to the public while protecting the air, land, and water of the City of Los Angeles.

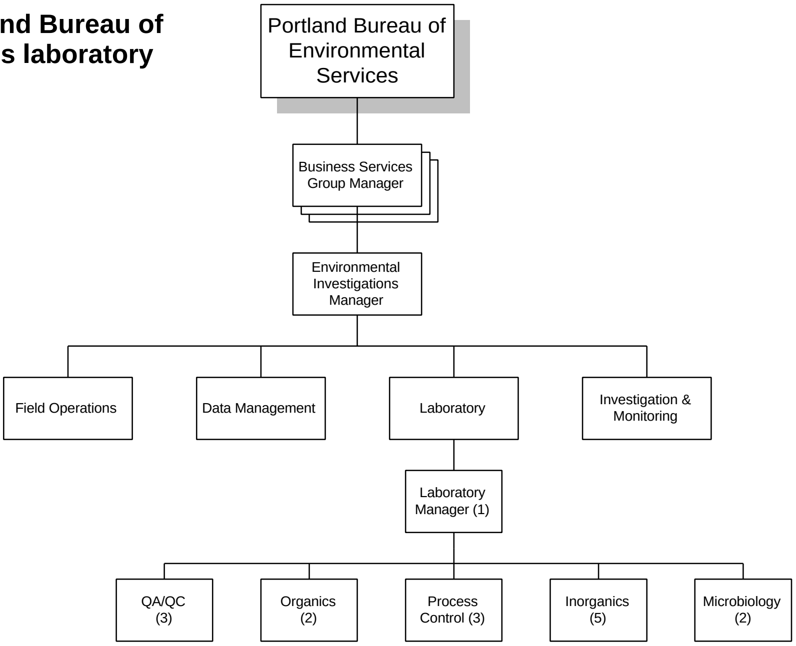
City of Portland Bureau of Environmental Services

The City of Portland's Water Pollution Control Laboratory is a full-service analytical laboratory that provides water quality analysis to all of the Bureau's water quality programs. The laboratory is located in the St. Johns area of Portland, approximately three miles from the Columbia Boulevard Wastewater Treatment Plant. The laboratory occupies approximately 11,000 square feet in a 37,000-square-foot building. Included in the laboratory are analytical areas for General Chemistry, Nutrient Analysis, Process Control, Organics and Metals Analysis. In addition, there are storage areas, prep areas, sample receiving/sample custodian areas and office space for the lab staff. The offices for Source Control, Field Operations, Spill Response, Data Acquisition and Management, Investigation and Monitoring and Industrial Stormwater Management are also located in the building.

Laboratory staffing for FY1997 was 16 people, including a Laboratory Manager, a QA/QC Chemist, an Inorganic Chemist, an Organic Chemist, a Process Control Chemist, and 11 Laboratory Technicians. The building receptionist (who is covered by the Administrative Support Section) performs all clerical responsibilities. The management of all laboratory data is assisted by a Laboratory Information Management System (LIMS). The laboratory reports to the Environmental Investigations Manager, who in turn reports to the Business Services Group Manager. The laboratory has five discrete sections: QA/QC, Inorganic Chemistry, Organic Chemistry, Process Control and Microbiology. The organizational structure is summarized in Figure 3:

The laboratory's operational hours are from 6:00 a.m. to 5:30 p.m., Monday through Friday. The laboratory is staffed on Saturday and Sunday for wastewater treatment plant process control/NPDES permit analyses; however, the building is not open to the public.

Figure 3: City of Portland Bureau of Environmental Services laboratory staffing.



In FY1996-97, the laboratory performed 70,131 analyses on 12,850 samples. The distribution of the work is as is shown in Table 1:

Table 1.
City of Portland
Bureau of Environmental Services
FY 1996-97 Laboratory Analyses

Wastewater Treatment	38%
Discretionary	(16%)
Required by Permit	(22%)
Source Control	28%
Stormwater Management	12%
Fresh Water Quality Mgmt.	18%
Miscellaneous	4%
TOTAL:	100%

Approximately 2% of the laboratory's workload is subcontracted to an outside laboratory.

City of San Jose/Santa Clara Water Pollution Control

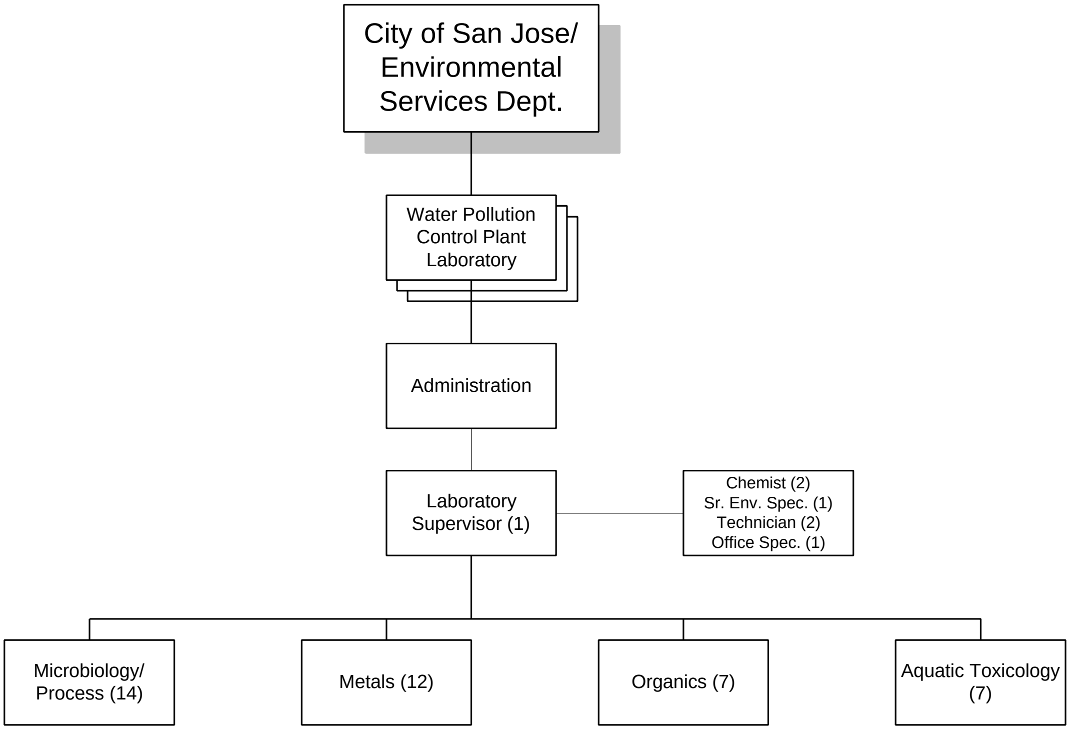
The San Jose/Santa Clara Water Pollution Control Plant Laboratory is located at the southern tip of the San Francisco Bay. The laboratory moved into a new state-of-the-art facility in 1996, providing over 12,000 square feet of laboratory space and 3,600 square feet of open office area. Special features include separate "clean rooms" for ultra-trace-level organic and inorganic analyses, dedicated HVAC systems optimized for trace level biological and chemical determinations, and specialized biomonitoring and culture facilities.

Staffing for FY1998 included a Laboratory Supervisor, two Research Chemists, one Aquatic Toxicologist, one Research Microbiologist, 11 Chemists, three Biologists, two Microbiologists, 21 Laboratory Technicians, and one Office Specialist. The Environmental Enforcement and Technical Support Division's also provide ancillary clerical support.

The laboratory is a full-service environmental testing facility that is certified by the California Department of Health Services for a variety of drinking water, wastewater and hazardous waste analyses. Major laboratory instrumentation includes graphite furnace and flame AAs, ICP, ICP/MS, a cold vapor mercury analyzer, ICs, GCs and GC/MSs. Laboratory data handling is accomplished with personal computers on a local area network utilizing various computer software programs, as well as PE Nelson's SQL*LIMS, which is in the process of being interfaced with all major laboratory instrumentation.

The laboratory reports to the Technical Support Division Manager, who in turn reports directly to the Director of the Environmental Services Department (ESD) for the City of San Jose. ESD administers the Water Pollution Control Plant for eight tributary cities in Silicon Valley. The laboratory has five work groups: Administration, Aquatic Toxicology, Inorganic Chemistry, Organic Chemistry and Process Control/Microbiology. The analytical sections are supervised by the research chemists, the research microbiologist and the aquatic toxicologist, each of whom reports to the laboratory supervisor. Chemists are directly responsible for sample receiving QA/QC activities, and they report directly to the Laboratory Supervisor. The organizational structure is summarized in Figure 4:

Figure 4: City of San Jose/Santa Clara Water Pollution Control laboratory staffing.

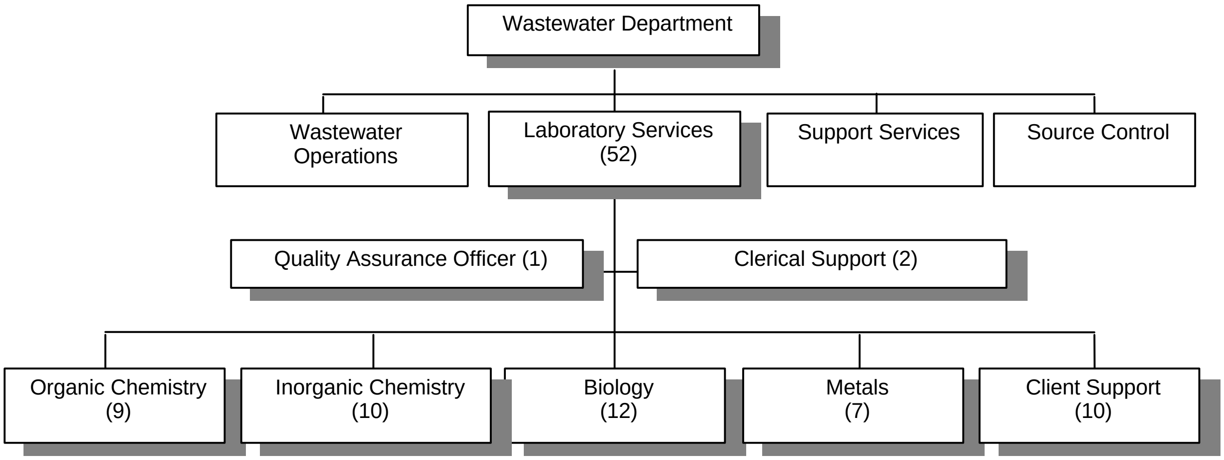


The laboratory analyzes approximately 90,000 samples per year. Analyses conducted include volatile and semi-volatile organics, chlorinated pesticides and PCB's, microbiology (including pathogens), priority pollutant metals, acute and chronic toxicity and conventional chemistry parameters.

East Bay Municipal Utility District

The Laboratory Services Division is a full-service, production-oriented, environmental laboratory that provides analytical support for the East Bay Municipal Utility District's (EBMUD) water and wastewater systems. The laboratory serves as a central facility for managing all EBMUD analytical services except on-site process monitoring performed by treatment plant operators for operations control purposes. The State of California Environmental Laboratory Accreditation Program (ELAP) certifies the laboratory for water, wastewater and hazardous waste analyses in 17 separate fields of testing. In FY1997, the laboratory was organized into four analytical sections and one support section as shown in Figure 5:

Figure 5: East Bay Municipal Utility District laboratory staffing.



Administratively, the two clerical support staff are not assigned to the laboratory's budget, however, functionally they both work for the Laboratory Services Division. In FY1997, two positions remained vacant throughout the year, thus the total staff count for budgetary purposes was 50.

Located at EBMUD's main Wastewater Treatment Plant near the Oakland Army Base, the laboratory occupies approximately 30,000 square feet of analytical and office area. The District's laboratory also manages a second 800-square-foot remote laboratory at the District's North Richmond Water Reclamation Plant.

The laboratory's Mission is: To provide analytical data to address the regulatory, operational and project-related needs of the District. As a full service, production oriented, environmental laboratory, we strive to provide high quality, legally defensible data for our clients in the most efficient, cost-effective way possible.

In FY1997, the laboratory was staffed as follows: 1 manager, 5 section supervisors, 34 analysts, and 10 support staff (clerical, purchasing, LIMS, QAO, client services and safety). With the exception of limited on-site monitoring programs, the laboratory is not responsible for sample collection and delivery. The laboratory analytical staff are divided into the following job classifications: Research Chemist (2), Chemist I/II (7), Microbiologist I/II (3), Lab Technician III (11), and Lab Technician I/II (11). Support staff include: Senior Chemist (4), Senior Microbiologist (1), Quality Assurance/Safety Officer (1), LIMS Administrator (1), Clerical (2) and Temporary Worker (1). Administrative staff include: Manager (1), Supervising Chemists (3), Supervising Microbiologist (1) and Aquatic Toxicologist (1).

Laboratory staff work several alternative work schedules (standard 8-hour days, compressed workweek schedules, and staggered work hours and days) to functionally extend the laboratory's operation from 6:00 a.m. to 6:00 p.m. on Monday through Friday, and from 7:45 a.m. to 4:15 p.m. on Saturday and Sunday.

In FY1997, the laboratory performed approximately 130,000 analyses on 60,000 samples distributed among the analytical groups as shown in Table 2:

Table 2.
East Bay Municipal Utility District
FY 1997 Laboratory Analyses

Metals	37,650
Microbiological	30,350
Biomonitoring	100
Organic chemical	3,300
Inorganic chemical	58,650

The distribution of analytical costs for this work between the District's water and wastewater systems was approximately 63.3% water (31.65 FTEs) and 36.7% wastewater (18.35 FTEs). Out of an adjusted laboratory budget of $4,884,422 developed in the Benchmarking Unit Cost Model, this would translate to a water system budget of $3,091,839 and a wastewater system budget of $1,792,583.

The wastewater component of the laboratory's budget can be further broken down in Table 3:

Table 3.
East Bay Municipal Utility District
Laboratory Wastewater Budget

Discretionary laboratory support	37.9%
Required compliance monitoring	37.4%
Source control monitoring	13.5%
Special programs & projects	5.5%
Research	2.9%
Wet weather program monitoring	1.9%
Other non-specific work	0.9%

Beyond the typical equipment and skills needed for conventional water and wastewater chemical and microbiological analyses, the District Laboratory is also equipped and staffed for:

- Pathogen monitoring using advanced microscopic procedures;
- Biomonitoring using both acute and chronic assays;
- TOC and TOX monitoring;

- Low-level metals analyses using GFAA (2), HGAA, ICP and ICP/MS, and
- Low-level organic chemical monitoring using GC (6), GC/MS (3) and HPLC (1).

The types of analytical procedures used by the laboratory for both the water and wastewater systems are quite diverse. In each of the analytical groups, the number of distinct United States Environmental Protection Agency (US EPA), Department of Health Services, or in-house procedures used is shown in Table 4:

Table 4.
East Bay Municipal Utility District Water and Wastewater Systems Analytical Procedures

Procedures	Number of Methods
Metals	11
Microbiological	22
Biomonitoring	8
Organic chemical	39
Inorganic chemical	79
TOTAL	159

King County Department of Natural Resources

The King County laboratory system includes two process laboratories, one at each treatment plant (Renton and West Point), and the Environmental Laboratory located centrally in metropolitan Seattle. Organizationally, the process laboratories and the Environmental Laboratory are in different divisions within the Department of Natural Resources. The process laboratories are part of the Wastewater Treatment Division, and the Environmental Laboratory is part of the Water and Land Resources Division, as shown in Figures 6 and 7.

Each process lab employs six to seven process specialists, who are supervised by a chief process analyst. The process labs are part of the treatment plants' Process Control Units, which include personnel such as process engineers and process analysts who do not perform laboratory functions. Each process control section has a supervisor who reports to the plant manager. The process laboratories perform conventional chemistry and microbiology analyses in support of plant process optimization and NPDES requirements. The process laboratories also provide support to capital projects such as effluent reuse and the Applied Wastewater Technology (AWT) program. Computer specialists within the process control group provide LIMS support in one of the process laboratories. In the other process laboratory, LIMS is supported by centralized services in the Wastewater Treatment Division. Process lab specialists and treatment plant operators share sampling duties at the plants.

The Environmental Laboratory employs approximately 70 staff including chemists, biologists, microbiologists and environmental specialists. Environmental Laboratory staffing also includes support positions such as sample manager, QA officer, laboratory assistants and laboratory project managers. The organizational structure of the Environmental Laboratory includes five analytical labs plus field sampling, data management, and client services groups. Each group has a supervisor who reports to the laboratory manager. Analytical capabilities of the environmental laboratory include conventional chemistry, organic chemistry, trace metals, microbiology and aquatic toxicology.

The Environmental Laboratory provides support for NPDES permit requirements, the biosolids and source control programs, as well as receiving water, collection system, CSO, and lakes and streams monitoring. The Environmental Laboratory also provides sampling and analytical support for wastewater capital projects such as effluent reuse, construction projects, facilities planning, and AWT, as well as services to other public agencies and non-wastewater funded groups in King County on a reimbursable basis. Approximately 2% of the operating workload is subcontracted, primarily for analyses that lack sufficient volume to make them cost effective to perform in-house.

Program support costs for the process labs were determined based on time-per-test data, and the number of analyses per process area to develop a relative percent effort per area. This figure was applied as a multiplier to consumable and other non-labor operating costs and applied to the calculated lab support cost for each operational area of the plant. The Environmental Laboratory expenditures were allocated to multi-agency template categories based on data from the timekeeping system. The Environmental Laboratory staff charge their time to customer projects and in-house activities such as method development. These data were used to calculate the percentage of workload for the template categories, which were used to apportion the Environmental Laboratory expenditures that remained after expenditures such as benefits and training were allocated to other areas of the template. Expenditures for the process and environmental labs were allocated to the lowest level of template detail possible based on detail available from the time keeping system. Field sampling expenditures were allocated to the template category corresponding to the process area they support, and environmental laboratory expenditures for non-wastewater related operations were allocated to the Z category.

Discretionary monitoring refers to all analyses that are not directly required by permit. Many of these discretionary tests are essential to optimize plant performance to meet effluent discharge limits. For example, suspended solids tests in the secondary process area are used to determine solids inventory and, ultimately, wasting rate. Approximately 85% of the monitoring performed at the treatment plants is discretionary. All non-permit required influent monitoring costs were assigned to the source control category. Biosolids monitoring included work to support the agency’s beneficial Reuse Land Application program, which includes monitoring required by the 503 regulations. Source control monitoring includes analyses in support of the Industrial Pre-Treatment program, the Industrial Surcharge program, the Key Manhole Monitoring program, and any source tracing conducted in response to elevated levels in plant influent samples.

Expenditures in the non-source control, non-required monitoring category include work on a receiving water ambient monitoring program, trouble call, and non-required CSO monitoring in the collection system. Method development efforts in 1997 included seawater and ultra-trace metals by ICP-MS, automated conventional chemistry tests, tributyl tin, and improvements to microbiology methods. LIMS and PC support expenditures were high primarily because of the level of data management staffing maintained at the environmental laboratory. These staff support all the lab PCs; the lab’s local area network and connection to the wide area network; the LIMS system; the maintenance of the 35-year historical database; and customer and public information act requests for electronic data and reports. They have also spent a significant amount of time in the study year responding to specialized format sediment data requests from the Washington Department of Ecology and preparing laboratory systems for the year 2000.

Figure 6: King County Department of Natural Resources process laboratories staffing.

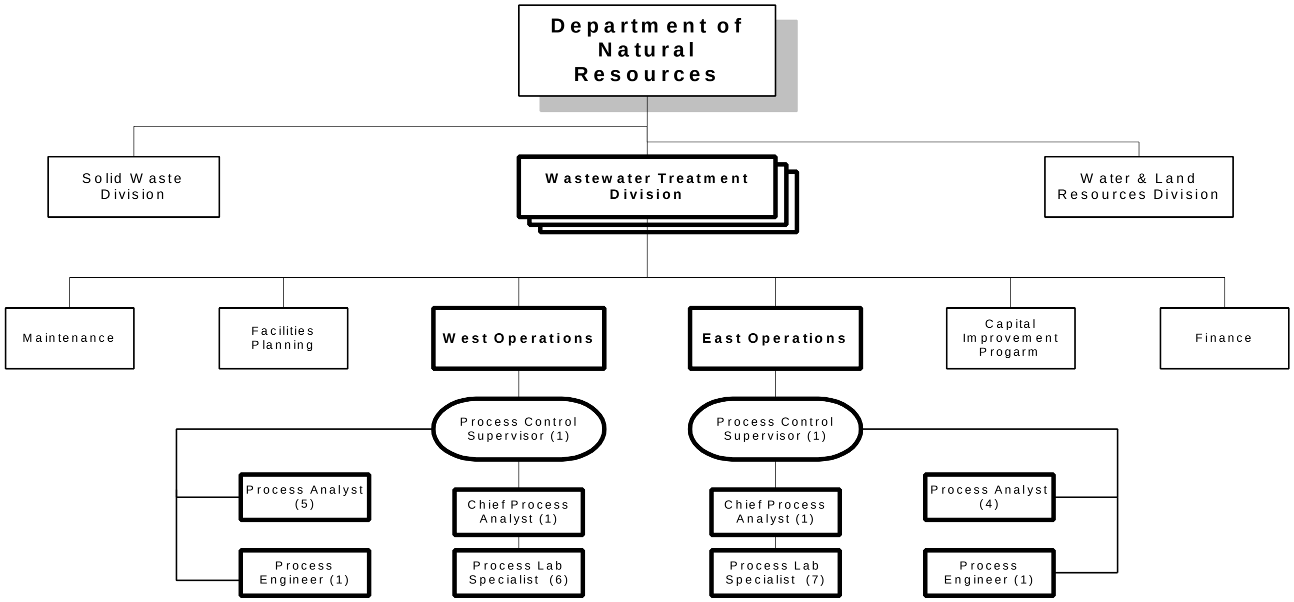
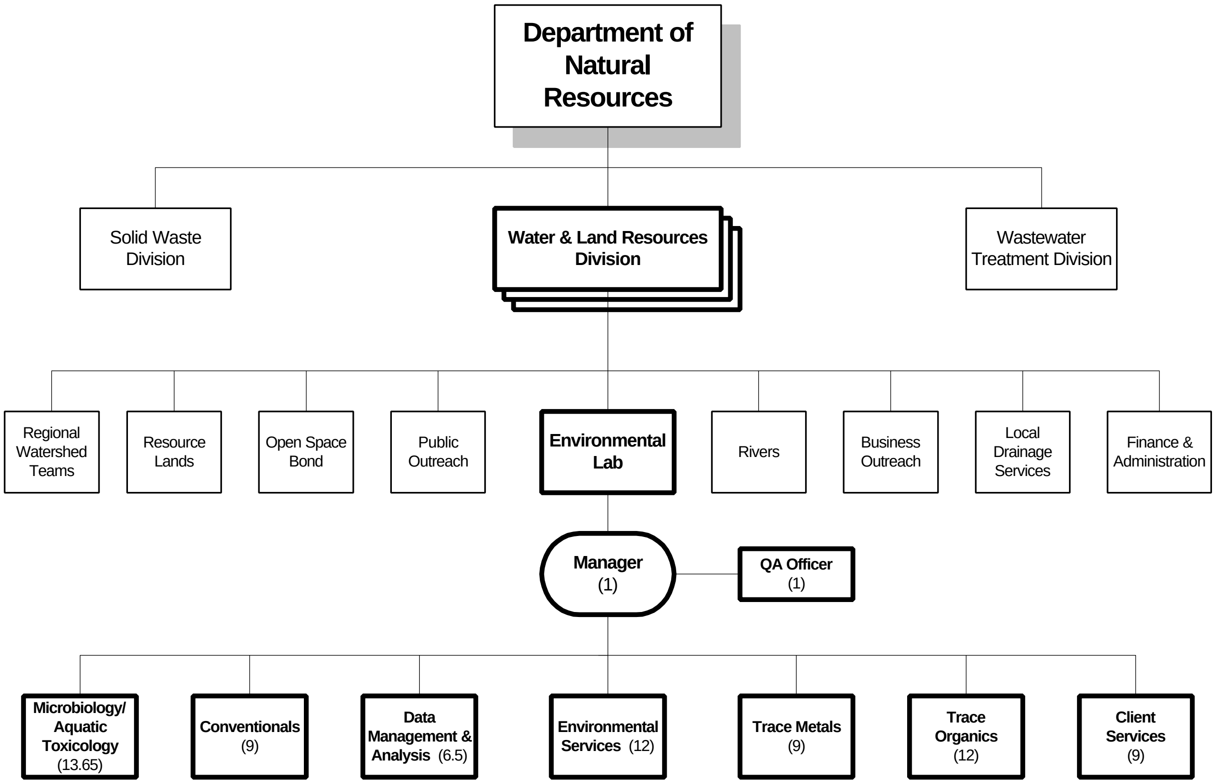


Figure 7: King County Department of Natural Resources environmental laboratory staffing.



Massachusetts Water Resources Authority

The Central Laboratory of the Sewerage Division of the Massachusetts Water Resources Authority (MWRA) is located at the Deer Island Treatment Plant. The laboratory opened in 1995 as part of the Boston Harbor Project to improve water quality by constructing a 1.2 billion-gallon wastewater treatment plant and upgrading the remainder of the sewerage infrastructure. The laboratory reports to the Environmental Quality Department (ENQUAD), making it organizationally separate from its clients: Wastewater treatment, NPDES, Toxic Reduction and Control (Industrial Pre-Treatment), Residuals Management (biosolids fertilizer pelletizing plant), Harbor Studies, and Waterworks Division.

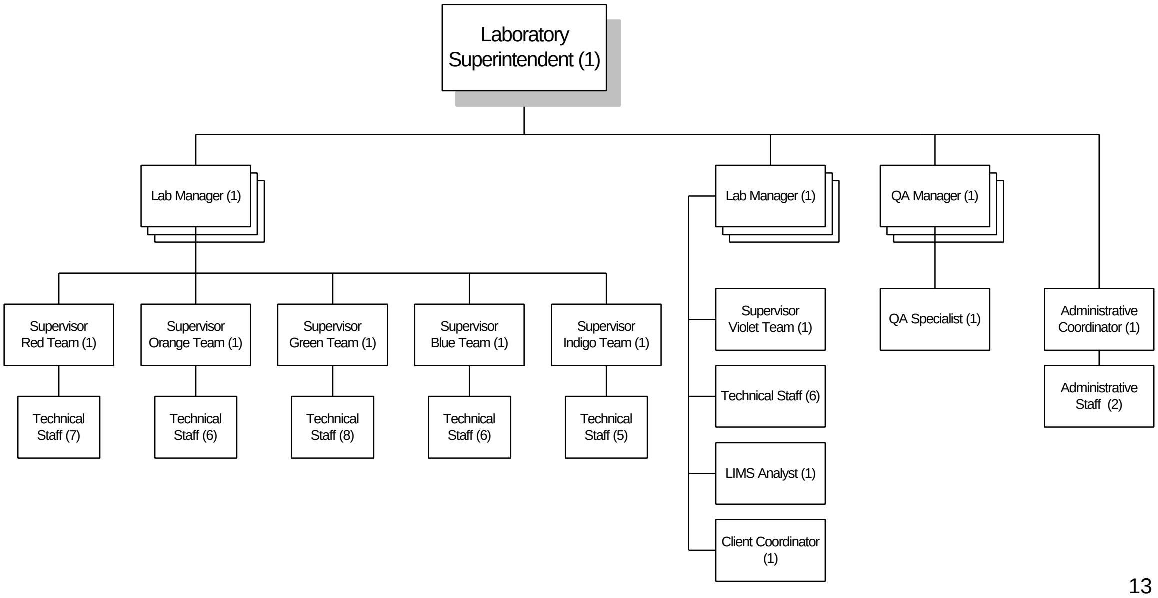
There are approximately 55 regular staff at the environmental laboratory, including chemists, biologists, microbiologists, technicians, and support staff. Several interns and contract employees are available to augment the laboratory's capacity. The organizational structure of the environmental laboratory includes six laboratory teams, covering the testing areas of microbiology, conventional chemistry, trace metals and trace organics, plus field sampling/sample management, and client services. Each team has a laboratory specialty plus several other tests. The team reports to a supervisor, who in turn reports to a laboratory manager, as shown in Figure 8.

The laboratory conducts compliance sampling at the treatment plant; otherwise treatment plant operators or other clients collect samples. Approximately 2% of the operating workload is subcontracted, primarily for analyses with insufficient volume to make it cost effective to do the work in-house.

Laboratory staff charge their time and supplies purchases to specific tests or to other general categories (e.g., training, method development), and these data were used to calculate the production rates (hours per test) for all types of tests.

The laboratory has an extensive quality assurance/quality control (QA/QC) program to ensure that client's laboratory needs are met. This includes certification from the Massachusetts Department of Environmental Protection for testing both drinking water and wastewater. The laboratory also participates in the annual NOAA "National Status and Trends" (Mussel Watch) interlaboratory performance evaluation program for both trace organics and metals.

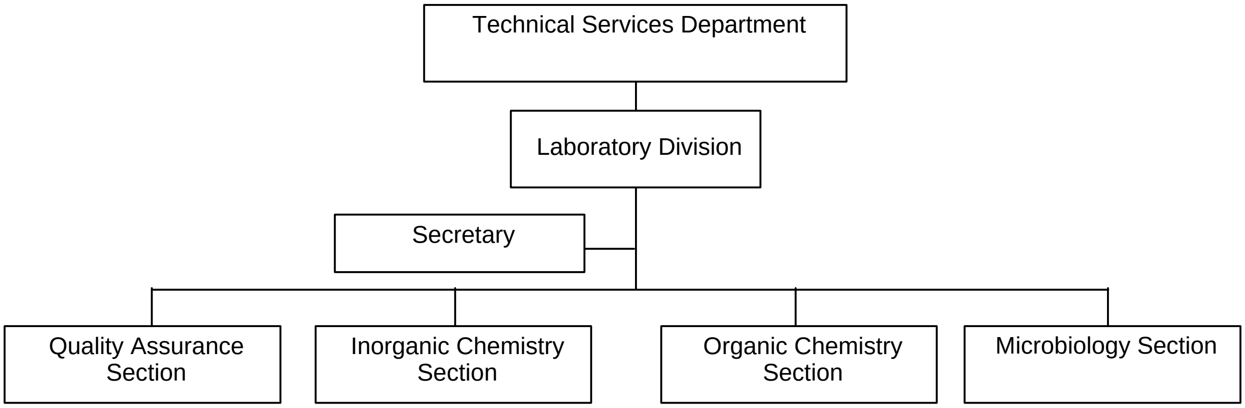
Figure 8: Massachusetts Water Resources Authority laboratory staffing.



Orange County Sanitary District

The Orange County Sanitary District laboratory reports to the Director of Technical Services and is organized into a general administrative function and four laboratory sections: Quality Assurance, Microbiology, Inorganic Chemistry (including trace metals) and Organic Chemistry. The laboratory has a staff of 35 FTE including approximately three FTE for sample collection. The LIMS support functions are managed within the Quality Assurance Section (Figure 9).

Figure 9: Orange County Sanitary District laboratory staffing.



The lab occupies approximately 20,000 square feet of a two-level steel-and-concrete building that was designed and built in 1990-91 specifically as a laboratory building. The mission of the laboratory is to provide analytical services in support of operations, compliance, and source control activities and to conduct research directed toward improving the effectiveness of the laboratory and in furthering the overall mission of the sanitation district. Approximately 100,000 analyses, not including quality control samples, are performed annually.

The laboratory defines its role in terms of its customers and its ability to provide analytical services in support of their programs. In order to meet the analytical and compliance related needs of our customers, it is accredited with the California Department of Health Services Environmental Laboratory Accreditation Program.

The distribution of testing by customer group is:

Table 5.
Orange County Sanitary District Distribution of Testing by Customer Group

NPDES Required	26.2%
Source Control	23.1%
Plant Process Support	30.8%
Solids Testing	13.8%
Air Standards Compliance	1.2%
Special Projects Incl. Engineering	6.0%

The laboratory internally performs about 98% of the required testing, and 2% is performed at contract laboratories.

All permit required bioassay work is performed at contract laboratories. Some non-permit, research directed bioassay testing is performed within the Environmental Compliance and Monitoring Division (ECM) which is also part of the Technical Services Department. The ECM Division through contract with SAIC or other consulting services manages all receiving water and ocean monitoring studies.

The first priority of the laboratory is to support various programs involved in the treatment of wastewater. These programs include compliance with the NPDES permit, support of wastewater processing operations, support of the source control pre-treatment monitoring process, and support of the ocean receiving water monitoring program, including surfzone microbiology monitoring.

Laboratory staff also participate in various engineering project teams. Their role is to provide expert advice in chemistry and microbiology and to properly coordinate and conduct analytical work that flows from the projects into the laboratory.

The distribution of costs within the various wastewater treatment areas, defined in the Benchmark Template, were determined by multiplying the annual number of each type of test by the fully burdened cost for each type of test. These costs were then summed for all type of tests.

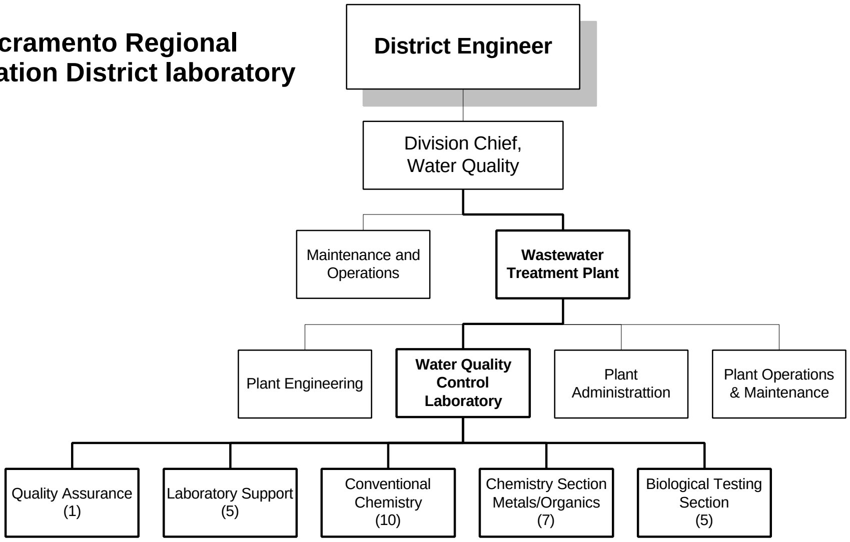
The laboratory at OCSD is responsible for developing and publishing the NPDES Discharge Monitoring Report. This is a function that requires approximately 2 FTE, over and above normal data reporting, and is not routinely performed by other laboratories in the benchmark study.

Sacramento Regional County Sanitation District

The Water Quality Control Laboratory is a part of the Sacramento Regional County Sanitary District’s 181 MGD pure oxygen activated sludge Wastewater Treatment Plant facility located on 3,300 acres of land approximately nine miles south of downtown Sacramento. The usable square footage of the laboratory facility is approximately 13,000. Laboratory support and administrative spaces include offices for the lab manager, supervisors and senior staff and clerical support, as well as a sample receiving room and a common prep-room area. The analytical areas include space for biological, conventional, metals and organics testing. There is also floor space and rooms provided for chemical, gas, glassware supply and equipment storage. A remote, 700-square-foot laboratory facility exists at the effluent discharge station on the Sacramento River, where the District’s state-of-the-art continuous flow-through acute fish bioassay tests are conducted.

The laboratory reports directly to the Wastewater Treatment Plant Manager. The Wastewater Treatment Plant Manager reports directly to the Chief of Water Quality, who oversees the maintenance and operations section of the wastewater collection and treatment systems. The District Engineer reports directly to the District Board of Directors. The laboratory has four discrete work groups that include the Biology, Chemistry, Conventional Chemistry, and Lab Support Sections, each headed by a section supervisor who reports directly to the Laboratory Manager. One QA/QC officer position reports directly to the laboratory manager as well. The organization structure is shown in Figure 10:

Figure 10: Sacramento Regional County Sanitation District laboratory staffing.



A total staff of 29 was assigned to the laboratory for the FY1997. Employees included a lab manager, two supervisors, four chemists, three biologists, 13 journey-level technicians (five senior environmental laboratory analysts, eight environmental lab analysts), and four apprentice-level technicians (two lab assistants and two lab helpers). Two clerical support positions assigned to the laboratory, whose salaries came out of the Plant's Administration Section budget, were included in overhead costs.

The Chemistry Section is primarily involved in testing for low-level concentrations of metals and organic components of environmental samples. It is divided into two sub-sections for Metals and Organics analysis. The metals testing section is certified to conduct low-level metals analysis on water and wastewater samples with GFAA, FAA, ICP-MS instrumentation. Low-level mercury analysis is conducted using a cold vapor mercury analyzer. In the organics testing part of the Chemistry Section, GC analyzers are used to conduct US EPA 601, 602, and 608 tests on environmental samples. Digester gas and cyanide gas analyses are conducted in the Organics Section. Although neither organic nor metal, testing for nitrate, nitrite, chloride, ammonia, and ortho-phosphate analyses are conducted in the Chemistry section using a Lachat segmented flow auto-analyzer.

The Conventional Chemistry Section performs standard wet chemistry and physical tests that include solids testing (total and suspended), moisture, TKN, pH analyses, conductivity, turbidity, H_2S volatile acids, CODs, and MBAS analyses for process monitoring and permit required testing.

The Biology section conducts biologically related testing including:

- Bacteriological analyses (total/fecal coliform, salmonella, fecal streptococcus, E. coil, and heterotrophic plate counts) of water, wastewater, and biosolids;
- Algae identification and cell counts;
- Continuous flow-through and static fish bioassays;
- Chlorophyll *a* analysis;

- Helminthes ova tests on biosolids;
- ELISA tests for diazinon and chlorpyrifos; and
- Bioluminescence toxicity analysis.

Some specialty testing for treatment plant applications are also conducted in this section, including radical length determination, surface tension, flourometry, viscosity, O_2 consumption rate, microscopic assessments of activated sludge mixed liquor samples, *Nocardia sp.* identification and enumeration testing, mixed liquor foam tests, and germination index.

The Laboratory Support/Administration Section includes the Lab Manager, LIMS administration, Quality Control/Quality Assurance program administration, Data Management administration, program coordination, clerical staff, and customer relation functions.

The workload can be divided into the wastewater operations support (related to template categories) and wastewater capital support. The overall laboratory workload to support wastewater operations is 75.1%. Of that amount, 39.5% is discretionary and 35.6% is related to compliance monitoring (28.0% required and 7.6% special programs). The workload associated with wastewater capital support was included in the operations support. Approximately 18.4% of the total workload represents costs related to capital support including special studies for new facilities such as constructed wetlands, biosolids dewatering, biosolids classification study, ultraviolet disinfection study, and dedicated land disposal for biosolids.

Testing activities conducted for agencies outside of the Water Quality Division are directly reimbursable to the Treatment Plant through a journal voucher system and direct billing. Services that fall into this billing category represents approximately 5% of the laboratory's total workload and includes drinking water and well water coliform testing.

Approximately 13% of the FY1997 laboratory budget covered costs for work sent to outside laboratories. Work is sent to outside laboratories when: 1) workload exceeds capacity; 2) resource limitations (staff, equipment/instrumentation or space); 3) instrument failure; or 4) lack of certification to perform the requested procedures. The laboratory determines the appropriate course of action to take based on the above-listed factors.

Labor costs for the laboratory during the FY1996-97 can be divided in the following activity groupings (Table 6):

**Table 6.
Sacramento Regional County Sanitation District
Laboratory Labor Costs FY 1996-97**

Discretionary monitoring	39.4%
Compliance monitoring	35.6%
Source control monitoring	8.2%
Special programs and projects	7.6%
Laboratory support	8.9%

The laboratory performed approximately 62,000 billable tests on 25,000 samples during the FY1996-97. The workload was distributed as follows among the analytical groups (Table 7):

Table 7.
Sacramento Regional County Sanitation District
Billable Tests FY 1996-97

Section	Tests by Section	% of Total Tests
Metals	9,946	16.1%
Biology	4,655	7.5%
Organics	1,606	2.6%
Conventional chemistry	45,709	73.8%
TOTAL	61,916	100%

Work assignments are diverse and vary from performing standard tests at the bench, to participating as technical experts in special studies, to program coordination, to participating in routine field monitoring and sampling operations of the receiving water in support of a multi-agency Coordinated Monitoring Program (CMP) of the Sacramento River. The laboratory has a boat, sampling equipment and staff dedicated to contribute the necessary resources and support for the monthly CMP events. In addition, staff may be assigned to participate in various capacities in support of numerous District and other Agency programs. Some of these other programs include:

- Sampling and monitoring of the bufferland groundwater wells;
- Sampling and testing of soils from dedicated land disposal areas used for biosolids disposal;
- Collecting and analyzing potable water samples for the County-owned and -operated Water Maintenance Districts; and
- Sampling and monitoring the Plant’s bufferland ambient onsite streams.

Cross training of staff is emphasized to allow for maximum operating efficiency and flexibility in allocation of resources.

Process Benchmarking Summary

Early in the benchmarking process, the laboratories established an extensive list of process benchmarking questions in the following categories:

- Human Resources;
- Support Systems;
- Planning;
- Data Management;
- Analytical Work;
- Safety and Waste Management; and
- Quality Improvement.

Each laboratory manager completed the survey (Appendix A) and shared the results with the others in the group. The results of the process benchmarking survey were condensed into an abbreviated table format to facilitate comparison (Appendix B). The process benchmarking table and information shared in meetings helped laboratory managers identify “best practices” among the laboratories. Best practices were defined as management tools or laboratory practices that contribute to efficiencies, improved operations, better customer service or higher quality data. The best practices fell into four categories, which are discussed below:

- Workload Management;
- Customer Service;
- Employee Development and Morale; and
- Staffing Strategies.

Workload Management

1. Minimizing the cost-per-test is mostly a function of **optimizing batch size to best utilize laboratory capacity**. Lab managers also felt that it was helpful to have a predictable and somewhat stable workload. Some of the laboratories reported that they had gained efficiency by working with customers to best match the schedule and size of sample batches with laboratory capacity. Laboratories have also found it helpful to coordinate scheduling to minimize weekend and off-hours work as much as possible, thereby reducing costs for overtime. A sporadic workload and customer needs for rapid turnaround are not conducive to optimizing batch size.
2. One agency has implemented a policy that requires **the agency lab be given the right of first refusal for all of the agency’s laboratory workload**. This way, the lab is fully responsible for managing both the data and the data quality of the agency’s analytical workload. The agency also gains purchasing efficiencies of scale for contract lab services. Agency resources that had been used for contract management can be redirected. The lab has increased opportunities to optimize the batch size of their own workload; and can better project and plan for resource needs from year to year.
3. Some laboratories reported improved operations through the **implementation of a project manager approach**. Laboratory Project Managers work closely with clients to evaluate their short- and long-term analytical needs, often on an annual basis. Lab managers

who have implemented project manager systems reported improved communication between the laboratory and customers by providing a single point of contact, as well as a reduction in the number of interruptions for bench analysts. Laboratory Project Managers are expected to be familiar with customers' projects and make scheduling decisions and provide consulting services on behalf of the laboratory. Lab consulting services include providing assistance in developing cost-effective sampling and analysis plans that address project data quality objectives. While some laboratories have reported success by implementing project management as a separate section with dedicated project managers, other labs have reported success by assigning this function to supervisors and other laboratory professionals. This model allows supervisors and scientists to expand beyond their traditional laboratory functions, and it has been found to be positive for morale. The choice of model may be related to the scope of the laboratory. Labs with fewer customers, most of whom are internal to the agency, may benefit most from assigning project management functions to laboratory supervisors and scientists. Labs with more customers and/or customers who are external to the agency may find that a dedicated project management system works best in their organization.

4. When lab managers compared times per test for various analytical methods, laboratories with higher efficiency often were those with **higher levels of automation**.
5. Within the limits allowed by regulations, lab managers reported increased efficiency by **implementing more productive methods**. For example, replacing single-element graphite furnace AA methods with multiple-element ICP-MS technology for low detection limit work significantly reduces the per-element analysis time.
6. Some laboratories reported reduced supply and hazardous waste disposal costs by **"miniaturizing" analyses and reducing volumes** whenever possible.
7. Some laboratories reported savings by not setting up to do a particular test in house if there is not sufficient workload to make the test cost effective, or if the cost of developing and implementing the method is not cost effective
8. One laboratory reported they manage workload by having **annual meetings with their customers to evaluate programs based on data quality objectives**. Based on this information, the laboratory programs are readjusted every year.

Customer Service

1. Some laboratories reported that they had established **customer advisory or monitoring committees**. In one example, the advisory committee is composed of representatives from major client groups. The committee meets with the lab manager to provide direction and strategic planning insight from the perspective of the customer. Discussion topics are wide ranging and include: lab performance (including criticisms); anticipated method development and resource needs; and opportunities for cost savings such as workload reductions. In another laboratory, the committee focuses on prioritizing needs for laboratory resources and identifying opportunities for laboratory customers to coordinate data uses. The premise of these committees is that the lab is not an infinite resource, and the customers need to work with the lab to balance workload and set priorities. An additional reported benefit of the committee is that clients hear each other's perspectives, recognize conflicting interests, and better understand lab decisions.
2. Some laboratories reported success in working with regulatory authorities and customers to reduce or modify monitoring requirements.

3. One laboratory reported that they had found it both educational and beneficial for customers to spend a day in the laboratory to see how their samples are processed. Often laboratories are portrayed as “black boxes” that receive samples and send out results. Hands-on experience in the laboratory can help customers understand the process of producing high-quality analytical data.
4. Several laboratories reported invoicing systems that they felt were beneficial for customers. In some cases, the systems are required because of multiple fund sources such as wastewater and drinking water, and in other cases the systems are informational. Lab managers feel that in either case, these systems provide cost accountability for clients.
5. One laboratory reported success with customer surveys. Data from customer surveys have helped the laboratory to identify and focus on issues such as turnaround time and flexibility of services that are important to the customers.

Employee Development and Morale

1. One laboratory reported success with a **career progression system that allows employees to advance as they gain proficiency and meet rigorous performance standards**. As a measure of the success of the system, this laboratory reported that their output had increased four-fold since the system was implemented, while budget and staffing had increased two-fold. This laboratory also reported that the staff proficiency and reduced turnover attributed to this system has helped them successfully transition to an increasingly complex workload.
2. Lab managers reported success with providing **professional development opportunities for staff motivation**. For example, one laboratory budgets $300 per year per person for discretionary training.
3. One laboratory reported success with the implementation of **continuous quality improvement training**. Staff are expected to take responsibility for identifying efficiencies and streamlining processes in their work. They are taught to look for problems with systems rather than blaming others, and they are encouraged to problemsolve based on data and performance measures. Another laboratory reported success by establishing clear lab performance goals such as 21-day or less turnaround time for 95% of all analyses and reports, less than 0.5% exceedance of hold times, less than 0.5% lost analyses, and 100% of billing invoices delivered to customers on time.
4. One laboratory reported the use of an **annual staff survey tool to identify issues that affect morale and productivity**. Annual administration of the tool enables lab management to monitor trends over time and to track success in addressing issues raised in the previous survey.

Staffing Strategies

1. One laboratory reported success with an **interdisciplinary team structure that provides flexibility to move people around to respond to workload fluctuations**. Another laboratory reported a similar strategy that involves cross-training staff in other analytical areas and shifting resources as the workload shifts.
2. One laboratory reported salary savings **by hiring clerical staff to do clerical work so scientists can focus on analytical work**. Other laboratories reported success with strategies such as reallocating vacancies to lower levels before filling them and considering not filling vacancies whenever possible.

It is important to note that various combinations of best practices may improve lab performance depending on individual circumstances, but this is not intended to be a checklist of steps to be taken by all the laboratories. What works well in one laboratory may not fit well with the program and workload needs of another laboratory. For example, some laboratories reported salary savings by limiting the number of scientists and assigning routine tasks to technicians. However, laboratories with more complex workloads felt they would not be able to meet analytical requirements with this approach to staffing. Also, one laboratory that had previously staffed with a split of technicians and scientists reported employee morale problems and a lack of flexibility to respond to workload fluctuations.

Performance Benchmarking Summary

Performance benchmarking, or metric benchmarking, is a quantitative tool that captures the numerical input and output of each laboratory. Performance benchmarking in this study consisted of two major products:

1. Input to the multi-agency performance benchmarking template; and
2. Development of a detailed budget model and extensive cost-per-test comparison spreadsheet.

As noted above, all laboratories participated in the cost-per-test comparison, and only those agencies in the multi-agency study input data to the performance benchmarking template.

Multi-agency Template

In order to compare the costs for the multi-agency template, the laboratory data were normalized to lab full time equivalents per million gallons per year multiplied by 1,000 (FTE/MGY*1000) and laboratory expenditures per million gallons per year (lab $/MGY, Appendix C). It is important to note that the costs in the laboratory template include only those costs associated with analytical work. Costs for activities such as sampling, although they may be included within the budget of a given agency, have been allocated to the program with which they are associated. For example, the costs associated with sampling for NPDES monitoring requirements have been included in T. 1. C. 3. a (technical support NPDES permits). Those laboratories that perform work for non-wastewater programs such as drinking water or hazardous waste backed these costs out of the expenditures reported in the multi-agency template.

When costs are compared for the wastewater operation categories such as discretionary monitoring or source control, there are two components that contribute to the variation:

1. The scope of work requested; and
2. The laboratory's efficiency in performing the work.

The consensus among laboratory managers is that the scope of work component contributes most to the cost. The number and type of analyses that are requested by customers have the most impact on the analytical cost of a given monitoring program. To a lesser extent, the cost is influenced by the efficiency with which the laboratory performs the analyses. This is not to diminish the importance of laboratory efficiency in identifying cost savings. However, the laboratory can only explain a small percentage of the cost differences between agencies for a given template category (such as discretionary monitoring or source control) based on cost-per-test differences. A comprehensive analysis of the cost differences needs to include input from the customer group responsible for determining the sampling and analysis plan for a given category.

As discussed above, process benchmarking suggested that laboratories should work closely with customers to optimize batch size and sampling schedules. Another suggestion from process benchmarking was the importance of implementing laboratory project management systems. The most significant benefit of project management is the collaborative relationship that evolves between the laboratory and its customers when they work together to develop cost-effective sampling and analysis plans. Through this process, both parties are responsible for addressing the cost-effectiveness of monitoring programs associated with the scope of work cost driver. On the other hand, the laboratory benchmarking effort focused on analytical cost-effectiveness. The remainder of this section will focus on the comparison tool that was developed to compare budgets, costs-per-test and productivity.

The first step in calculating costs-per-test was to develop a cost model that would generate comparable budgets for all the participating laboratories. The goal was to begin with “apples-to-apples” budgets that included the same components. This step involved decisions about which activities (and associated budgets) to include in the model. For example, there are some costs (such as field sampling) that are not included in everyone’s budget. In order for agencies to compare their budgets on an “apples-to-apples” basis, the group needed to make a decision about whether to include sampling costs in the model. If the decision was made not to include such a cost, then the agencies with this component in their budget would back it out for purposes of the model. On the other hand, if a decision was made to include a cost that some agencies did not have in their base budget, then these agencies had to add that cost to the model. For example, it was decided that the cost of equipment depreciation would be included in the model because it is a major cost of analytical work. Laboratories whose capital equipment budget resides in another part of the agency budget had to add this cost to their budget in the model. Details of these budget decisions are listed in a summary table (Appendix D).

After developing comparable budgets, the next step was to calculate overhead burdened average salary costs for the four major analytical areas (metals, organics, biology and conventional chemistry). Overhead was defined to include two components:

1. Administrative overhead (management, support such as QA/QC and LIMS, etc.); and
2. Section overhead (supply costs, supervision, equipment depreciation, etc.).

A budget spreadsheet was developed to ensure that costs were correctly allocated to direct and overhead categories, and that overhead costs were calculated uniformly (Appendix E).

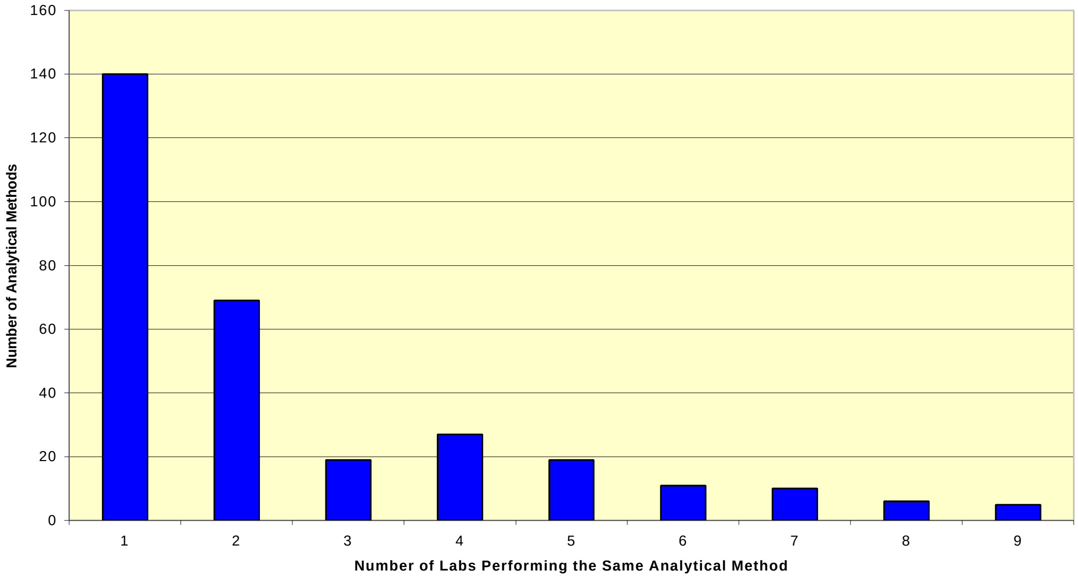
The next step was to calculate the cost for each analysis by multiplying the overhead burdened hourly rate by the number of hours required to do the test. For example, if the average hourly rate including overhead for organic chemical analyses is $60 and the time required to do a PCB analysis is two hours, then the cost for a PCB analysis for that laboratory is $120. In all, 222 analyses, differing in test of constituent or test method, were included in the cost/test spreadsheet. Again, a spreadsheet was developed to ensure uniform identification of analytical methods and consistent calculations (Appendix F). The cost-per-test exercise has been a valuable tool to compare both cost- and time-per-test data for various analyses, as well as the numbers and types of analyses performed by each laboratory. Because there may be more than one available method to analyze for a given parameter, the cost-per-test table is also useful for comparing the efficiencies of various methods, such as automated versus manual procedures.

Another measure that the laboratories agreed to generate was a “reconciled cost-per-test.” Once the study year data were loaded for times-per-test and the number of analyses performed by each method, it was possible to calculate the total budget covered by that year’s workload using the average hourly rate data generated earlier. Because laboratory staff does not spend 100% of their time doing analytical work, the total revenue is typically less than the total budget included in the model. The reconciliation process involves multiplying the cost-per-test by a cost adjustment factor that forces revenue to equal the budgeted cost for each analytical section. A table of the reconciliation or cost adjustment factors is found in Appendix G.

Cost adjustment factors have been useful to the laboratories as a comparison tool and as an indication of the amount of time spent in “indirect” activities. There has been considerable discussion, for example, about the relationship between "capacity" and the cost adjustment factor. Each laboratory has its own work capacity and an associated sample throughput volume and rate that optimizes the use of available staff and equipment. The consensus among the laboratories is that the better the sample volume matches the available capacity, the more efficient the laboratory, and hence the lower the cost adjustment factor. The laboratories have also developed a list of indirect activities and compared the percentage of staff time spent on indirect activities. In addition, the cost adjustment factor also adds a correction for errors in the estimation of the time per test figures.

In developing the cost-per-test model, the group agreed that analyses would be defined by method, with the exception of metals and ion chromatography analyses, which were defined by element. Benchmarking participants then spent considerable time developing a ten-page spreadsheet that contains an exhaustive list of all the different analyses performed by the nine labs in the study. One of the most interesting findings of the study is that there are only five specific methods of testing out of 222 in the table that are conducted by every agency. In addition, there are only five specific methods of testing out of 222 that are conducted by eight of the nine participating laboratories. The frequency data plotted in Figure 11 demonstrate the diversity of the workload for laboratories participating in the study.

Figure 11: Frequency distribution of the 222 analytical methods in the cost/test model.



The data in Figure 11 reinforce the group's observation of significant differences between the laboratories, despite the fact that they are all public sector laboratories that support wastewater treatment agencies. It also helps to explain some of the differences observed in the benchmarking study, which will be discussed later in this report. Although the lab managers noted significant differences, they also observed several similarities among the laboratories. For example, there was greater-than-expected similarity in the times-per-test and in the percentages of staff time spent on indirect activities.

The lab managers discussed factors that affect cost and productivity to better understand inter-laboratory differences for times and costs-per-test. Spreadsheets were generated comparing the number of tests-per-year (Appendix H), the cost-per-test (Appendix I), and the time-per-test

(Appendix J) by method for each agency. A summary table (Appendix K) was also produced to compare the number of tests-per-FTE-per-month by analytical area (microbiology, biomonitoring, general chemistry, organic chemistry and metals). Discussions of these tables produced the following observations about similarities and dissimilarities between laboratories that affect productivity. For the purposes of these discussions, productivity was defined by the metric tests/FTE/month.

Microbiology

1. Differences in sample matrices affect times and costs-per-test. Laboratories that performed primarily process-oriented water and wastewater analyses had higher productivity as defined by tests/FTE/month. Conversely, agencies that have a significant number of solid matrix samples such as biosolids and tissues had lower productivity
2. Agencies performing a significant number of pathogen analyses in addition to the indicator organisms tended to have lower productivity.
3. Lab managers observed that productivity followed a continuum of complexity for indicator organism analyses. The continuum from low to high complexity was fecal coliforms < total coliforms < fecal and total coliforms < *E. coli* < fecal strep. The laboratory with the highest productivity for microbiology tests had the highest proportion of tests for fecal and total coliforms.
4. Laboratories with high microbiological sample volume also had high levels of productivity, which was credited to optimum batch sizes.
5. The times-per-test for microbiology analyses range from a low of less than half an hour for some indicator organisms to highs of 10 to 20+ hours for some pathogens. Therefore, laboratories performing tests for complex pathogens such as *Salmonella sp.*, *Listeria sp*. and enteric virus had lower levels of productivity than those who do not conduct a significant proportion of pathogen testing
6. Laboratories involved in significant levels of method development had lower levels of productivity. One laboratory also reported lower levels of productivity due to staffing for future, anticipated workload.

Biomonitoring

1. Chronic assays require significantly more time than acute assays, which explained the higher productivity for two laboratories that conduct only acute analyses.
2. More staff time is required to culture organisms in house than to purchase organisms for testing. Therefore, laboratories with significant in-house culturing efforts tended to have lower productivity. It should be noted, however, that the decision to rely on in-house culturing efforts might be dictated by factors outside the laboratory’s control.
3. The Microtox assay was included in the biomonitoring section. However, it requires significantly less time than other biomonitoring procedures (an hour versus days in some cases). As a result, including Microtox numbers in the tests/FTE/month metric caused the measure to range from 332 for a laboratory conducting only Microtox analyses to less than 10 for labs conducting only acute and chronic bioassays. Therefore lab managers felt that the Microtox numbers needed to be factored out to provide a meaningful comparison of biomonitoring productivity data.
4. Laboratories that are involved in method development or research efforts reported lower levels of productivity. Such activities may be the direct result of customer requests.

5. Productivity was observed to be inversely proportional to the diversity of tests conducted by the laboratory. The three laboratories that conducted the highest number of different assays (five, eight and nine different tests) had lower productivity numbers. Likewise, both the complexity of the assays and the batch size inversely influence productivity.
6. Three of the laboratories maintain remote operations where biomonitoring assays are conducted, which was observed to lower productivity. The assumption is that this reduced productivity is related to transportation and maintenance time associated with remote operations.

Conventional Chemistry

1. Productivity was proportional to the level of process monitoring tests (i. e., the higher the percentage of process monitoring conventional chemistry tests, the higher the productivity). This is because process monitoring tests tend to be less complex and are submitted to the lab in higher numbers. To a lesser degree, this also applies to microbiology as noted above.
2. One laboratory suggested that their lower level of productivity for conventional chemistry tests might be due the lack of an analytical group devoted to conventional chemistry testing. Instead, this laboratory spreads its conventional chemistry workload among another analytical areas, which provides a more equitable distribution of workload and improves staff morale.
3. The laboratory with the lowest level of productivity for conventional chemistry attributed this to low numbers of samples and underutilized laboratory capacity. Likewise, laboratories that reported inefficient batch sizes demonstrated lower productivity.
4. Some laboratories with high levels of productivity for conventional chemistry reported that automation increased their productivity.
5. One laboratory attributed lower productivity levels for conventional chemistry to their organizational structure. This laboratory reported that multiple laboratories resulted in reduced productivity related to inefficient batch sizes.
6. One laboratory reported that orientation of new staff had negatively impacted their conventional chemistry productivity numbers for the study year.

Metals

1. The laboratory with the highest level of productivity for metals analyses attributed their success to replacing the more labor-intensive graphite furnace analyses with ICP-MS technology. The same laboratory also had a particularly high workload during the study year, which helped them to optimize batch sizes and efficiency. In addition, they extended hours for metals laboratory operations to meet workload demands by maximizing use of instrumentation.
2. Instrumentation issues resulting in lower productivity are most commonly related to problems with instrument reliability and the lack of ICP and ICP-MS technology. One laboratory found their productivity was severely limited by having to use an outdated ICP instrument incapable of automated gas shutoff, which meant the instrument could not be run overnight.
3. Requirements to meet ultra-trace detection limits or work with complex matrices (such as seawater and tissues) negatively impacted productivity for metals analyses. Likewise, significant method development efforts tended to lower productivity for metals analyses.

4. One laboratory explained their higher level of productivity for metals analyses by customer requests for a high number of elements-per-sample. The reader may recall that metals analyses were counted by element, whereas other analyses were counted by method. Therefore, multiple element ICP and ICP-MS technologies cost little more to analyze for 15 elements than for one element per sample.
5. One laboratory attributed their low productivity for metals analyses to inefficiencies associated with decentralized operations. This is because fewer samples are processed at each laboratory facility with redundant staffing and instrumentation, resulting in lower efficiency.

Organic Chemistry

1. Laboratories that conduct a significant number of less-complex analyses demonstrated higher levels of productivity for organic analyses. Conversely, laboratories with low detection limit requirements and complex matrix samples tended to have lower levels of productivity for organic analyses.
2. Significant method development efforts accounted for lower productivity for organic analyses.
3. Productivity for organic analyses was observed to be inversely proportional to the variety of analytical methods conducted by the laboratory. Laboratories that focus on a smaller variety of tests had higher efficiency levels for organic analyses. Conversely, laboratories conducting a greater diversity of tests tended to have lower levels of productivity for organic analyses. This observation is linked to batch size and monitoring frequency. In extreme cases, laboratories sometimes analyze more samples for the method-required QC than samples themselves, in which case it may be more desirable to contract the work to an outside laboratory (unless there is an overriding reason to do the work in-house).
4. Laboratories that frequently experience less-than-optimum batch sizes had lower levels of productivity for organic analyses. One laboratory reported that their batch size was negatively impacted by their decentralized structure and resulting redundancies.
5. One laboratory attributed lower productivity to problems with instrument reliability.

Additional Context for the Study

This study was designed to provide input to the multi-agency benchmarking study and to allow comparisons among participating laboratories. Therefore, the study is not all encompassing, and some care should be exercised in using the results. Points to keep in mind when evaluating the study results are discussed below.

“Zeroing Out”: Reconciling the Test Cost Spreadsheet with a Lab’s Budget

In the reconciliation process described above, each laboratory was instructed to reconcile the test cost spreadsheet with the total budget included in the model. However, the spreadsheet only accounts for the routine testing performed by the laboratory. It does not include other activities, such as method development, consulting, meetings, or training. If the “hours-per-test” figures accurately reflect the actual time spend performing the test, there will be a certain amount of “unaccounted-for” time.

To make the spreadsheet and the budget reconcile, two options were considered:

1. Creating a reconciled (increased) cost-per-test; or
2. Inflating the hours-per-test figures.

Both options have the effect of increasing the cost-per-test figures. The group decided to apply the reconciliation factor to the cost/test numbers rather than the hours-per-test numbers to keep the process simple. Not distorting the hours-per-test figures also had the advantage of maintaining their value for comparing method efficiency.

The reconciliation factor takes into account two uncertainties in the numbers:

1. The hours-per-test figures are estimates; and
2. Analyst time is also spent on indirect activities such as method development, purchasing, training and meetings.

Rather than utilize a single reconciliation factor for all analytical areas, the group agreed to calculate an adjustment factor for each section. This accounts for the fact that different analytical areas in a given laboratory may have different levels of indirect activities.

Detailed Time Tracking versus Expert Estimates

Different laboratories took different approaches to getting hours-per-test figures. The approaches varied significantly, but fell into two general categories: 1) expert estimates; and 2) actual time tracking measurements. Expert estimates are obtained by asking a group of supervisors and/or analysts to determine how long it takes to analyze a batch of a certain number of samples. These estimates may tend to be aggressive because they are made with the assumption of not being sample-limited (optimum capacity utilization). They also may not accurately take into account factors that detract from efficiency, such as interruptions, conflicting/changing priorities, problem samples and reruns.

Time tracking may produce more accurate measurements of how long each test takes to perform, but it requires considerable effort. In this approach, everyone fills out a weekly time tracking form that details how time was spent on specific tests and a limited number of general categories such as purchasing and training. For the system to be successful, lab staff must recognize the need for accurate time tracking and take responsibility for entering accurate data into the system. If too much time is charged to a test, it will appear inefficient. If too little time is charged to a test, insufficient resources will be budgeted for that test. One advantage of a good time tracking system is that it can be used to monitor on-going performance and improvements because it takes into account the actual batch sizes used and the effects of interruptions or changing priorities.

Limitations of Test Count Comparisons

Although simple performance metrics, such as tests-per-person, are easy to compute, they do not necessarily facilitate meaningful comparisons. Some tests are performed quickly while others take hours. Tests-per-person measures in areas such as organic chemistry and biomonitoring with time-consuming tests were considerably lower than test-per-person measures in areas such as conventional chemistry, metals and conventional chemistry with less time consuming tests. However, the laboratory managers observed that comparing tests-per-person by analytical area provides more meaningful comparison than comparing test-per-person person on a lab-wide level. If the mix of tests between two laboratories is different, comparisons of tests-per-person vary even more at a lab-wide level and have limited relevance.

Another factor to keep in mind when comparing costs and times-per-test is the fact that there are additional “value-added” services that aren’t adequately captured in the detailed cost-per-test spreadsheet. Laboratories in the benchmarking study reported that they provide a wide variety of additional services beyond test results. These services include consulting, special studies, data interpretation, project designs, sampling and analysis plan development, special report preparation, and regulatory review and negotiation. For this study, these services were rolled into the laboratory’s overhead. Lab managers estimated that the percentage of time spent on these services ranges between 10% to 25%. Many of these services stem from a long-standing, customer-focused commitment to meeting the needs of the agency. These are often intangible benefits that are difficult to quantify, but their impact is significant.

Comparison of Benchmarking Costs, Marginal Costs and Prices

The costs-per-test in the detailed spreadsheet cover the actual cost for performing each analysis, subject to the assumptions in this study. In addition, the costs in the model do not represent marginal costs, which are the incremental cost for adding one more test to an existing batch of tests. The marginal cost does not include the cost of the instrumentation or the labor and supply costs associated with running and calibrating the instrument because these have already been accounted for in the study model. Likewise, marginal costs do not include the cost of QC samples when the sample can be added to an existing batch of samples that has not reached the QC limit. Marginal costs only include the actual labor and supplies associated with performing the additional tests. Therefore, marginal costs for additional work to fill the gap between existing workload and laboratory capacity are typically much lower than the costs in this study.

In addition, care must be taken when comparing costs in this study with commercial laboratory prices. First, it is important to keep in mind the difference between actual costs, which are fixed, and prices, which vary depending on factors such as market drivers and whether or not they reflect marginal costs. Second, it is important to factor in agency overhead costs associated with subcontracting work when evaluating commercial laboratory prices. Subcontracting analytical work requires procurement, contract management, QA/QC oversight, coordination, data management, and incorporation of the results in the agency’s historical database. Lab managers estimated that these activities add 10% to 30% to the cost of commercial laboratory prices.

After taking these factors into account, there may be situations in which it is more cost effective to sub-contract analytical work than to do it in-house, as has been noted previously in this report. One example is the situation in which there is insufficient annual workload to make it cost effective to purchase equipment and spend method development time required to establish a method in-house. Sub-contracting may also be beneficial even if a method has been established in-house in the event that samples do not arrive at the laboratory in sufficient batch sizes to make the work cost effective. For example, herbicide analyses that require considerable effort for one or two samples can be done more economically at a contract laboratory that can batch them with work from other customers. A sub-contract laboratory can also be helpful when instrumentation goes down, especially if samples are currently in-house and at risk of exceeding holding times.

Another point to keep in mind when evaluating the results of this study and considering cost-saving measures is the relationship between batch size and cost. It is important to evaluate whether proposed savings associated with reduced sample volume would be marginal costs or actual costs. Depending on the magnitude of the reduction, fewer samples may only reduce the number of samples in an analytical batch rather than reduce the number of analytical batches. As a result, the cost-per-test may actually increase as efficiency decreases. This reinforces the importance of customers working closely with their agency laboratory to evaluate strategies to optimize laboratory utilization by scheduling samples as efficiently as possible.

Summary and Conclusions

MABS Findings

When costs are compared for MABS template categories, two components contribute to variation between agencies:

1. The scope of work requested, and
2. The laboratory's efficiency at performing the work.

The number and type of analyses that are requested by customers have the most impact on the analytical cost, and cost is influenced to a lesser extent by the cost of an individual analysis. Therefore, the cost differences between agencies for given template categories cannot be explained solely on the basis of cost-per-test differences.

One inter-laboratory comparison was total laboratory expenditures versus flow-normalized laboratory expenditures, as shown in Figure 12. The bars in Figure12 represent the total annual laboratory expenditure for each agency, and the connected points represent laboratory expenditures normalized by annual flow. In general, the gap between total expenditures and flow-normalized expenditures narrows as annual flow increases. These data are considered to demonstrate the economy of scale factor that is achieved for larger systems.

Figure 12: Laboratory costs as total $ and $/MGY.

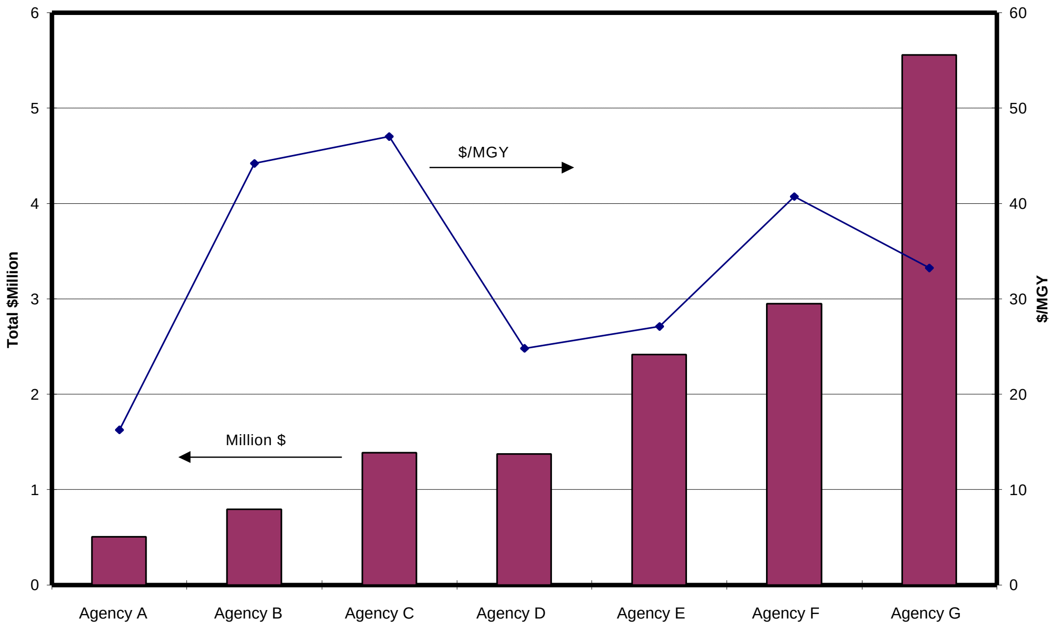


Figure 13 shows lab costs displayed by template categories as a percent of the total lab cost for each agency. This information provides additional context as agencies discuss differences in levels of laboratory support for wastewater operations, source control, and monitoring programs.

Cost Model Findings

A "productivity" metric was calculated for each analytical area (biology, microbiology, organic chemistry, metals chemistry and conventional chemistry). The comparison of these numbers formed the basis of a discussion about factors that either positively or negatively affect productivity. Laboratory managers also shared information on best practices that they had found to be successful in addressing efficiency, customer service, data quality, and cost effectiveness. Following is a list of key findings that were identified in these discussions.

1. **Minimizing the cost-per-test is mostly a function of optimizing batch size and best utilizing laboratory capacity**. Batch size affects cost-per-test because a predefined number of quality control (QC) samples are required at a fixed rate per analytical batch. For example, if there are 20 samples in an analytical batch and the QC rate is 5%, then one set of QC samples is required for these 20 samples. Depending on the analytical method, the QC set may include several different samples such as matrix spikes, duplicates, blanks, and standard reference materials. The same set of QC samples is required whether the batch size is one sample or 20 samples. Therefore, the cost-per-individual-test is lowest when batch sizes are run at their maximum capacity.
2. **Regarding the utilization of laboratory capacity**, there are several fixed costs associated with maintaining instrumentation and other aspects of the laboratory. If the laboratory capacity is under-utilized, these costs are spread across fewer samples, and the cost-per-analysis increases. Conversely, the cost-per-analysis decreases as the percent of laboratory capacity utilization increases.
3. **Laboratory analysts can streamline analytical procedures** by employing the most efficient methods and instrumentation, they can use process flow analysis to improve sample processing, and they can investigate ways to reduce reruns associated with problems such as QC failure. However, for the reasons stated above, minimizing the cost-per-test is mostly a function of optimizing batch size and efficiently utilizing laboratory capacity.
4. **It is critical for laboratories to work closely to schedule workload efficiently.** The best way for laboratories to achieve the cost reductions associated with optimizing batch size and efficiently utilizing laboratory capacity is to work closely with customers on scheduling. This is particularly important for samples with short holding times that provide less flexibility for batching. One best practice example of a useful scheduling strategy was the agency that established a policy giving their laboratory the right of first refusal for all agency lab work.
5. **It is critical for laboratories to work closely with their customers** to develop cost-effective sampling and analysis plans that address data quality objectives. In addition to doing things right, it is important that laboratories do the right things. The wise use of laboratory resources requires that laboratories work closely with their customers to ensure they are doing the appropriate analyses that best meet the customer’s project needs and data quality objectives.
6. **Flexible staffing strategies help laboratories respond to workload fluctuations**. Once workflow has been leveled as much as possible through improved scheduling with customers, the laboratory can work internally to improve their ability to deal efficiently with peaks and valleys in the workload if they have cross-trained staff who can shift from areas with less work to areas with workload peaks.
7. **Laboratories with higher efficiency often were those with higher levels of automation.** In addition to faster throughput and higher levels of productivity, laboratory automation can improve laboratory accuracy and precision.
8. **Factors such as variety of analyses offered, complexity of analyses and matrices, extent of QC and reporting requirements, and detection limit requirements affect laboratory efficiency and productivity.** Lab managers reported that productivity and ef-

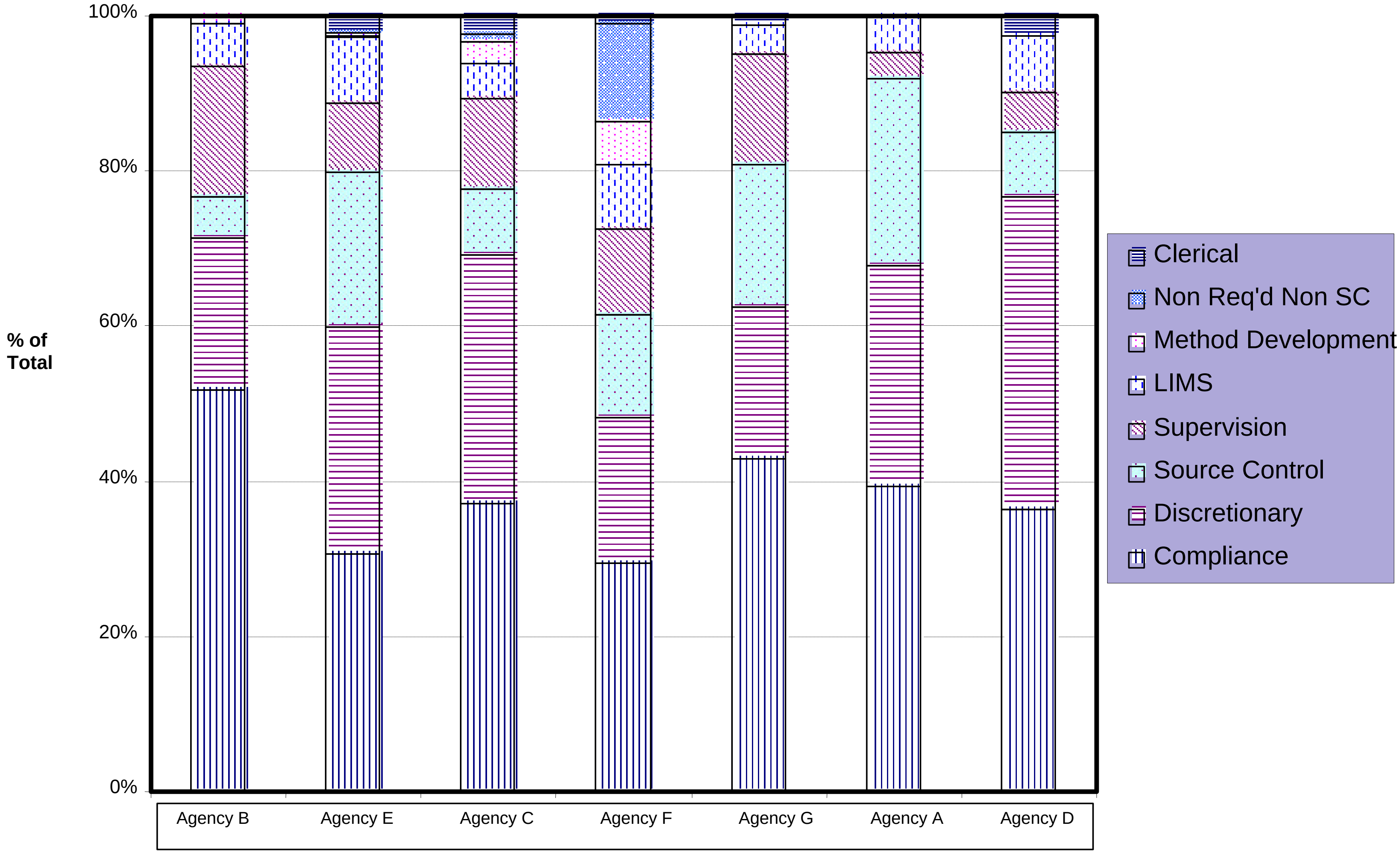
ficiency decreased as analytical complexity and the variety of service offerings increased. The most efficient laboratory for organic chemistry analyses, for example, conducts only three different analyses compared with a high of 39 different analyses. Other complexities such as very low detection limits requirements or difficult matrices were also observed to lower productivity

9. **Tools such as customer surveys, customer advisory committees, staff surveys, project management systems and job progression help laboratories improve customer service and employee morale**. For example, labs with customer advisory committees found they helped customers work with the lab to balance workload and set priorities. They also found it beneficial for customers to hear each other's perspectives, recognize conflicting interests, and better understand lab decisions. Customer surveys were reported by some laboratories to help identify and focus on issues that are important to their customers. Project management systems help improve the coordination between the laboratory and customers, and that is important in optimizing utilization of laboratory capacity and developing good sampling and analysis plans. In addition to improving employee retention and morale, job progression systems were reported to help laboratories improve their flexibility to respond to workload fluctuations by increasing the level of cross-training.

Areas for Further Study

Laboratory managers agreed that it is important to continue to collect data in future years to monitor trends, to evaluate the success of efficiency measures, and to periodically share information with each other. They also agreed that it is important to work with customers to explain agency differences in analytical costs associated with wastewater treatment operations and monitoring programs. Laboratories also need to continue to strengthen relationships with customers because optimal and cost-effective use of laboratory resources is a collaborative process between laboratories and their customers.

Figure 13. Lab costs by template category as a percentage of total.



Appendices