The Evolution of Collection System Best Practices

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Abstract

The wastewater collection profession is experiencing rapid change. As new products, operating procedures, and workarounds are introduced in response to increasingly stringent government regulations, a changing workforce, climate change and advances in technology, our industry's 'best practices' continually evolve.

How does our profession become aware of, evaluate, and implement changes to existing practices? How do these changes impact the workforce and workplace, and how do workforces and workplaces influence changes that are made? When should new business practices and technology advancements become generally accepted? These are all important questions to be considered, especially when evaluating the applicability of best practices, adopting new technology, standardizing procedures, and providing industry-wide training.

One of the most highly regarded water and wastewater operator training programs in the U.S. has been working hard to ensure that the collection systems best practices reflected in its courses are up-to-date, relevant, and appropriate. First published in 1975, and with nearly 90,000 copies in print and used by over 25,000 operators and managers in accredited training programs, the OPERATION AND MAINTENACE OF WASTEWATER COLLECTION SYSTEMS, Volumes 1 and 2, have undergone several complete revisions throughout the years. Under the auspices and supervision of the Office of Water Programs, California State University, Sacramento (CSUS), a team of dedicated industry veterans has been using a painstakingly thorough approach to keep its operators and manager training manuals current.

While Volume 1 is currently being distributed in its Sixth Edition, and Volume 2 is currently being distributed in its Seventh Edition, this paper describes a 'behind the curtain' look at the often-mysterious process used to create the new Seventh Edition of Volume 1. Due for release in October 2014, with principal work complete, this paper provides a glimpse in how best practices are created, identified, and documented for the wastewater collection industry.

Keywords: wastewater collection systems, training, best practices, new technology, work processes, workforce issues

Introduction
The wastewater collection profession is experiencing rapid change. As new products, operating procedures, and workarounds are introduced in response to increasingly stringent government regulations, a changing workforce, climate change and advances in technology, our industry's 'best practices' continually evolve.

One of the most highly regarded water and wastewater operator training programs in the U.S. has been working hard to ensure that the collection systems best practices reflected in its courses are up-to-date, relevant, and appropriate. First published in 1975, and with nearly 90,000 copies in print and used by over 25,000 operators and managers in accredited training programs, the OPERATION AND MAINTENACE OF WASTEWATER COLLECTION SYSTEMS, Volumes 1 and 2, have undergone several complete revisions throughout the years.

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The demand to identify best practices and to keep supporting training manuals current comes from many sources, including:

- Regulatory agencies responsible for ensuring compliance with collection system safety regulations and also environmental and public health protection regulations,
- Collection system agencies using the manuals for training and system O&M, troubleshooting, and safety programs,
- Changes in the workplace, including its extended diversity, introduction of performance measurement systems, and graying of the workforce, sometimes resulting in regional consolidation of sewer agencies,
- Regional (geographic) work standards and preferences,
- Accreditation boards responsible for overseeing the certification of collection system operators,
- Growing trend of distance education training programs,
- Commercial vendors wishing their new products and technologies to be included in the training manuals.

Designed to train personnel in the safe and effective operation and maintenance of wastewater collection systems, Volume 1 emphasizes tasks performed by line maintenance crews and covers various types of collection systems and construction inspection, while Volume II shifts emphasis to lift stations, maintenance, and administration.

Figure 1
Operations and Maintenance
of Collection Systems,
Volume I

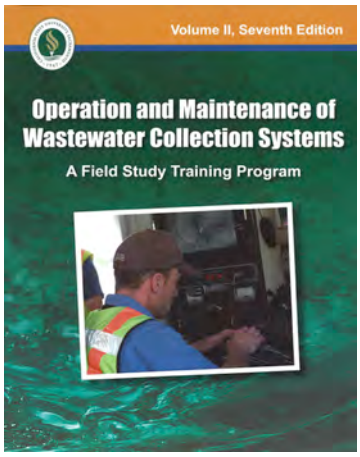
620 pp.

Chapter Titles – Volume I

1. The Wastewater Collection System Operator
2. Why Collection System Operation and Maintenance?
3. Wastewater Collection Systems (Purpose, Components, and Design)
4. Safe Procedures
5. Inspecting and Testing Collection Systems
6. Pipeline Cleaning and Maintenance Methods
7. Underground Repair

* Appendix: Final Exam, Words, Arithmetic, Index

Figure 2
Operations and Maintenance
of Collection Systems,
Volume II



734 pp.

Chapter Titles – Volume II

8. Lift Stations
9. Equipment Maintenance
10. Sewer Renewal (Rehabilitation)
11. Safety/Survival Programs for Collection System Operators
12. Administration
13. Organization for System Operations and Maintenance
14. Capacity Assurance, Management, Operation and Maintenance (CMOM)

* Appendix: Comprehensive Review Questions, Words, Index

From Idea to Action

All good things start first with an idea. And so it began with the creation of the OPERATION AND MAINTENANCE SYSTEMS manuals, including outside hounding, pestering, cajoling, and pleading.

As early as 1967, then Associate Professor, Kenneth Kerri, Ph.D., sitting in his office at Sacramento State College, recalls Bob Reed, Walt Driggs, John Brady, and Norm Farnham, all young wastewater treatment plant operators saying 'we want you to do a manual on how to teach us to do our jobs.' Continuing the impromptu roundtable, the group said that 'Managers know how to take certification exams, and Engineers don't know how to operate treatment plants.' But, Dr. Kerri recalls saying, 'I'm just a professor, I don't know anything about operating a treatment plant."

After continued pestering, and promises for once a week meeting, driving from all parts of Northern California, representing sewer agencies from Lake Tahoe, Fairfield, Modesto, Redding, Sacramento, and Stockton, Dr. Kerri reluctantly agreed, with the condition that 'everyone else would do all the work and write everything down, so that he would only have to shuffle the papers.

Weekly discussions started with a topic, such as lift stations, manholes, collection systems, treatment plants, etc. and asked the question, 'what would you tell a new person that knew nothing about.' With early meeting notes written in longhand, soon organized meetings began with oral presentations that were recorded, transcribed, typed, and circulated. Vendors were invited to participate and share photos, drawings, and troubleshooting tactics to operate and maintain their equipment.

By 1972, the core team included Bill Dendy, Bill Crooks, John Brady, and Dr. Kerri, with the Collection Systems Committee, particularly Rick Arbor from Minnesota and Richard Thomasson from Washington Suburban Sanitation Commission, reviewing and editing draft.

Noting the importance of adopting key requirements to create a successful teaching environment, professors in Education, including George Gardener and Larry Hanna from California State University, Sacramento, were enlisted to show how to learn a topic.

Following the successful results from the USEPA's national field study training program, OPERATION OF WASTEWATER TREATMENT PLANTS, a similar effort appeared desirable for wastewater collection system operators. In cooperation with the California Water Pollution Control Association, the project directors prepared and submitted a proposal to the USEPA for financial support through the Foundation of California State University, Sacramento. Chapters were written, presented at small information seminars, reviewed by consultants, and reviewers from throughout the United States, field tested by potential and experienced collection system operators, reviewed by the USEPA, and revised after each step in accordance with the suggestions and experienced gained from these sources.

While the USEPA paid for the development of course material, ongoing training and subsequent editions were self-funded from sale of manuals and enrollment in courses.

The First Four Decades

The first edition of the OPERATIONS AND MAINTENANCE OF WASTEWATER COLLECTION SYSTEMS was published in 1976. Referred to as a home study course, the first edition's Preface stated that the purpose of the wastewater collection system course, was to:

1. Develop new qualified wastewater collection system operators,
2. Expand the abilities of existing operators, permitting better service to both their employers and the public, and
3. Prepare operators for civil service and CERTIFICATION EXAMINATIONS.

The scope of each successive manual has included:

1. What collection systems are expected to achieve,
2. Why wastewater collection systems must be properly operated and maintained,
3. What the collection system operator is expected to do to keep the collection system functioning as intended,
4. How to inspect and test newly constructed sewer and new and old wastewater collection systems,
5. How to locate and evaluate problems such as stoppages, leaks, odors and lift station failures,
6. Selection of procedures and equipment to correct identified problems and to minimize recurrence of problems and failures,
7. How to operate and maintain inspection and cleaning equipment,
8. Methods of selection and application of chemicals,
9. Procedures for operating, maintaining and repairing collection systems,
10. Instructions for operating, maintaining, troubleshooting and repairing collection system equipment and facilities such as lift stations,
11. Techniques for recognizing hazards and developing safe procedures, and
12. How to organize and administer the operation and maintenance of wastewater collection systems.

Figure 3

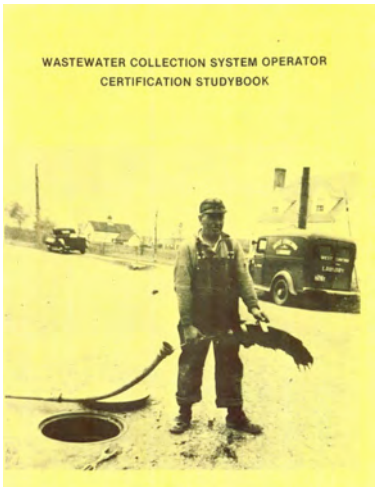


Table 4
Early Chapter Outline

COURSE OUTLINE

Chapter	Topic
1	THE WASTEWATER COLLECTION SYSTEM WORKER, by Walt Driggs
2	WHY COLLECTION SYSTEM OPERATION AND MAINTENANCE? by Walt Driggs
3	WASTEWATER COLLECTION SYSTEMS, by Steve Goodman
4	SAFETY, INSPECTING AND TESTING COLLECTION SYSTEMS, by George Freeland
5	PIPELINE CLEANING AND MAINTENANCE METHODS, by Dallas Hughes
6	UNDERGROUND REPAIR AND NEW CONSTRUCTION, by William Puthuff, Jim Hicks, Mel Arts and John Dolenga
7	LIFT STATIONS, by Manuel Munoz and John Brady
8	EQUIPMENT MAINTENANCE, by Lee Doty
9	SAFETY FOR THE COLLECTION SYSTEM WORKER, by Glenn David
10	ADMINISTRATION, by Neal Townley
11	ORGANIZATION FOR SYSTEM OPERATION AND MAINTENANCE, by John Brady, John Cavoretto and George Gardin
Appendix	
G	COLLECTION SYSTEM WORDS, by George Freeland
H	APPLICATIONS OF ARITHMETIC TO COLLECTION SYSTEMS, by Kenneth Kerri

TECHNICAL CONSULTANTS

John Cavoretto — William Garber
Ira Cotton — James Kemelr
George Gardner — Warren Prentice

Early versions of the manual established the foundation for successive manuals that followed. The manual was originally designed to allow for a self-paced instruction where operators work at their own speed. But, once collection system operators started using the manual for home study, they realized tat it could serve as a textbook in the classroom.

Colleges and universities used the manual as a textbook in formal classes, often supplemented by case studies offered by field supervisors and operators. Where colleges were not available

utility agencies and local chapters of wastewater organizations joined together to offer their own courses using the manual.

In order for the operator to certify successful completion for each chapter, objective tests and special answer sheets were provided when enrolled in the course. Rather than utilizing multiple choice, fill-in-the-blank, or True-False question formats, instead the manual used a narrative question format.

Figure 5
Sample Question Format

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 75.

3.2A List the sources or types of wastewater conveyed by wastewater collection systems.

3.2B What factors are considered in estimating peak flow from an area?

3.2C What measurement aids are commonly used to measure actual flow velocity in sewer mains?

In classrooms, instructors help answer questions when a person in the training program have questions or need assistance. Instructors then grade objective tests at the end of each chapter, record scores, and notify the Office of Water Programs at the California State University, Sacramento (CSUS), of the scores when a person successfully complete the program; avoiding any long wait while papers are graded and returned by CSUS. Recognizing the multi-cultural backgrounds of wastewater collection operators, previous educational experience of course participants, and slightly different meanings in some regions of the United States, Warren Prentice, was first to propose and author a section on key word pronunciation. Designed solely to aid operators, and often different from the WEBSTER'S NEW WORLD COLLEGE DICTIONARY, example key words are shown below:

The manuals pronunciation chart demonstrates the ongoing review and content analysis.

Figure 6
Sample Pronunciations

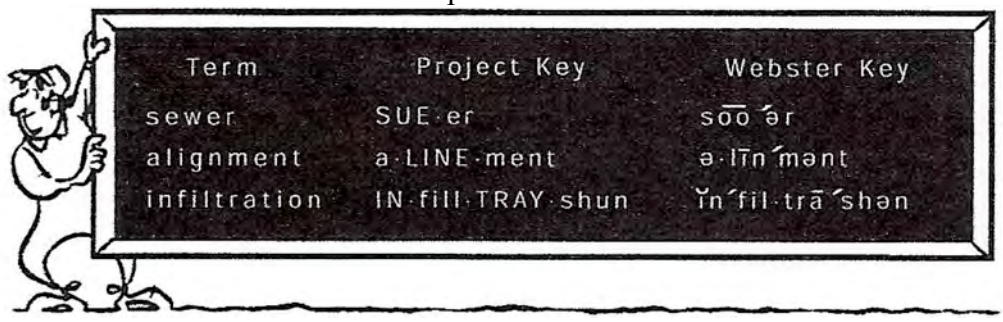


Figure 7

Table 1

WORD	SYLLABLE			
	1st	2nd	3rd	4th
sewer	SUE	er		
alignment	a	LINE	ment	
infiltration	IN	fill	TRAY	shun

The first word, *SEWER*, has its first syllable accented. The second word, *ALIGNMENT*, has its second syllable accented. The third word, *INFILTRATION*, has its first and third syllables accented.

Today, with 87,600 copies in print, nearly every collection system library, workbench, and bookshelf, include a copy of one or both Volumes of OPERATION AND MAINTENACE OF WASTEWATER COLLECTION SYSTEMS.

Figure 8
Volume 1 – Print History, By Edition

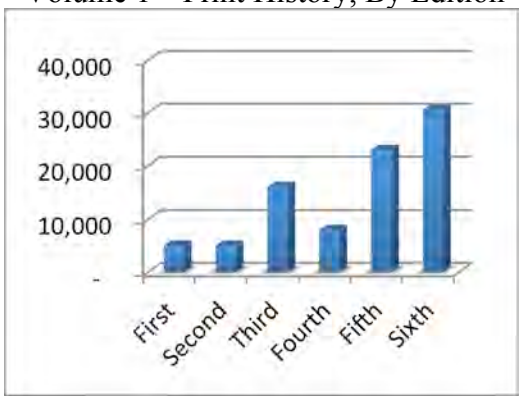


Table 2
Volume 1 – Print History

Year	Edition	Printing	Volume 1
1976	First	First	5,000
1983	Second	First	5,000
1987	Third	First	8,000
1991	Third	Second	8,000
1993	Fourth	First	8,000
1996	Fifth	First	8,000
1999	Fifth	Second	10,000
2001	Fifth	Third	5,000
2003	Sixth	First	15,000
2008	Sixth	Second	12,600
2013	Sixth	Third	3,000
TOTAL PRINTING			**87,600**

Table 3
Collection System Enrollments, 1991-2013

		Collection Systems Enrollments		
	Year	Volume 1	Volume 2	Total
1	1991	352	223	575
2	1992	670	381	1,051
3	1993	740	358	1,098
4	1994	768	396	1,164
5	1995	781	383	1,164
6	1996	842	385	1,227
7	1997	830	413	1,243
8	1998	882	454	1,336
9	1999	931	526	1,457
10	2000	754	376	1,130
11	2001	816	379	1,195
12	2002	812	410	1,222
13	2003	902	458	1,360
14	2004	780	438	1,218
15	2005	792	371	1,163
16	2006	765	424	1,189
17	2007	900	403	1,303
18	2008	750	435	1,185
19	2009	765	390	1,155
20	2010	760	385	1,145
21	2011	822	477	1,299
22	2012	831	442	1,273
23	2013	694	361	1,055
	TOTAL	**17,939**	**9,268**	**27,207**

Review Procedures

A key factor in the successful writing, editing, and publishing of a 'best practice' training manual is the ability to attract a cross-section of subject matter experts to enter into a collaborative review process. Collection agencies in California have provided a solid cross-section of the U.S. collection market, including size (i.e., large and small), climate (i.e. wet and dry weather), maturity (i.e. area-bound and new developments), land (i.e. coastal and inland), and disciplines (i.e., administrative, engineering, operations, human resources, and financial).

For many years prior to 1976 publication the first edition of the OPERATION AND MAINTENACE OF WASTEWATER COLLECTION SYSTEMS, Volumes 1 and 2, the Water Pollution Control Federation, its member associations, state and local utility agencies, and colleges and universities sensed a need for improvement in the dissemination of information on the operation and maintenance of wastewater collections. They felt a need for better training opportunities in the field; however, because of the lack of communication between the practical people doing the work in the field and the professional people in charge of publishing and training activities, the dissemination of information and training in the collection system field had been, until a few years earlier, almost negligible compared to that in the wastewater treatment plant field.

Prior to publishing the first edition, F. J. Ludzack, National Training Center, Office of Water Program Operations, EUSEPA, offered many technical improvements. Dr. Elie Namour, author of USEPA's "Manpower Manuals for Wastewater Collection Systems," reviewed the manpower aspects of the manual. Robert Rose, Program Manager, Chief, State and Local Training Activities Section, USEPA, served as an additional source of information and guidance.

No training book or manual can hold the attention of a reader if limited to just words; and the Collection Systems manual was no exception. With drawings by Martin Garrity, and sketches and line drawings by George Gardin and Sue Hashimoto, some of the best comments have been from its fanciful, almost comedic illustrations (Fig. 10)

Even the printer, Dave Clark, became a key player. As publisher of over 40 monthly magazines, campaign printer for both Democratic and Republican elected officials, and sports program printer for the San Francisco 49ers, San Francisco Giants, Oakland Raiders, and Oakland A's, Dave Clark offered off-peak printing rates and schedules for every manual that has been printed. Suggesting that a color photograph be included on the cover, a University photographer was tasked to provide photos of field crews.

Figure 10 – Using TV to Inspect Sewer Pipes, 1982

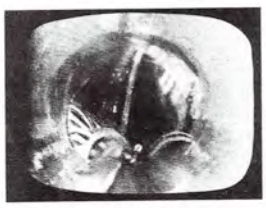
By 1987, Program Director, Ken Kerri, wrote how collection system operators had always survived by their wits and ingenuity. But, the tone of the manuals changed modestly to emphasize how operators were applying more advanced technologies to operate and maintain wastewater collection systems.

TV inspection technology, in use for almost 15 years, was gaining unprecedented acceptance by collection operators, with manufacturers introducing lighting, camera resolution, and mobility, that in turn allowed operators to begin to create acceptable defect identification standards.

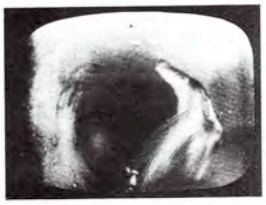
The TV technology used to inspect and record the status of collection systems is continually advancing. New instruments whose precision and reliability continued to improve over previous models, showed why authors, vendors, consultants, educators, reviewers, and operators, needed to work together to describe and integrate new products and techniques into later editions.

As personal computers migrated from the office into utility vehicles, a new set of roles and responsibilities crept into the lives of wastewater collection system operators representing a new tool to locate, inventory, and maintain, information to create a history of collection system assets. Previously limited to paper-based as-built maps stored in an engineer's drawer, operators soon became the front line to record work activities, conditions, and costs, able to be assigned to specific assets.

Figure 11
CCTV Problems

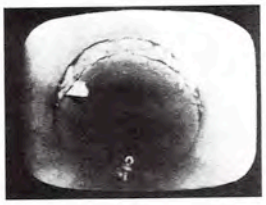


Infiltration at Defective Pipe Joint



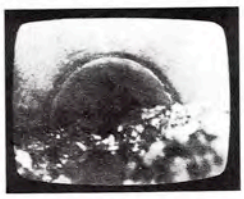
Infiltration or Inflow at Defective Service Connection

Protruding Service Tap



Drop Joint

Root Intrusion



Dirty Line, Gravel, and Debris

Table 4
TV Inspection Code System, 1987

Code	Description	Is this Okay? Y	N
INSPECTION INFORMATION		**Un**	
BDM	Brick de-mortared, but still intact	lf	☐ ☐
BMS	Brick missing, backfill showing	sf	☐ ☐
CAB	Camera blocked and unable to proceed further	ea	☐ ☐
CAS	Camera submerged	ea	☐ ☐
CAV	Cavity outside the line	ea	☐ ☐
CKL	Cracking, lateral, i.e. parallel to the direction of the flow	lf	☐ ☐
CKT	Cracking, transv., i.e., across the direction of the flow	lf	☐ ☐
COR	Corrosion, sulfide	lf	☐ ☐
CRS	Crushed	lf	☐ ☐
DAM	Damage, other causes, such as chemical attack	lf	☐ ☐
DEB	Debris accumulated in invert	lf	☐ ☐
DIS	Distorted shape, loss of concentricity	lf	☐ ☐
DWO	Dry weather overflow	ea	☐ ☐
FDP	Flow depth	in	☐ ☐
FIL	Infiltration flow rate	gm	☐ ☐
FLO	Inflow rate	gm	☐ ☐
GRS	Grease accumulation	lf	☐ ☐
INV	Invert damage, such as abrasion	sf	☐ ☐
JOI	Joint offset	in	☐ ☐
JOP	Joint separated longitudinally	in	☐ ☐
LEA	Leaking observed at deformed or missing seal	ea	☐ ☐
MDJ	Mineral deposit at joint	ea	☐ ☐
MHS	MH overflow or surcharging	ea	☐ ☐
MIN	Mineral deposits or scaling on pipe wall	lf	☐ ☐
MLS	Main line surcharging	ea	☐ ☐
NFT	Inflow of tidewater	gm	☐ ☐
ODR	Odor complaint	ea	☐ ☐
OTH	Other	ea	☐ ☐
RAT	Rat infestation	ea	☐ ☐
ROA	Roach infestation	ea	☐ ☐
ROO	Root intrusion	lf	☐ ☐
RUO	Mechanism rusted in open position	ea	☐ ☐
RUS	Mechanism rusted in shut position	ea	☐ ☐
SAG	Sagged line	lf	☐ ☐

Advancements in technology allowed collection system operators to perform more and more tasks without having to enter confined space of manholes or sewers, thus reducing the risk of exposure to safety hazards.

While the manual was first published in 1976 as a single volume, the manual was expanded by 1996 to require the addition of a second volume.

Rick Arbour helped to revise the Fourth and Fifth Editions and provided some of the graphics in the Sixth Edition. Gary Batis provided information on new technologies in the Sixth Edition and made many helpful suggestions to improve the usefulness of the Sixth Edition for collection system operators. The City of Fayetteville, Arkansas' David Jurgins and his collection system

crews, with Municipal Service Company Inc.'s Victor Coles, reviewed drafts of the Sixth Edition and made helpful suggestions.

For the most recent editions, work began in 2012 by nationally known and recognized collection system thought-leaders, including selected collection system experts, consultants, national associations, and commercial vendors, for their respective chapters, including:

California Collection System Agencies

- Sacramento Area Sewer District, John J. Hough and Randy Cannedy
- City of Sacramento, Department of Utilities, Robert Jack
- City of Los Angeles, Robert Potter
- Eastern Municipal Water District, Mark Chamberlin
- Union Sanitary District, Shawn Nesgis

National Perspective

- Tilson & Associates, Stephen B. Tilson
- Blue Heron Engineering, Laurie Chase

Vendor

- Technology - Chuck Hansen, former CEO Hansen Information Technologies

Considering New Products, Processes, and Procedures from Large and Small Companies

As the wastewater collection industry continues to undergo change, end-users, subject matter experts (SMEs), and editors are constantly on the lookout for better ways of getting things done. As municipal budgets get tighter, knowledgeable operators retire, and vacancies go unfilled, the need to adopt more efficient and effective best practices has never been greater.

Some industry changes represent incremental product innovations; smaller-scale improvements, extensions, or refinements of existing products that tend to have a certain ritual, rhyme, rhythm, or reason. Higher resolution CCTV cameras, improved flow monitoring algorithms, and enhanced user controls for jet trucks, represent just some incremental innovations. Often quite predictable, long-time established companies often introduce these improvements at regular intervals that are tested, reviewed, and substituted for older, legacy models.

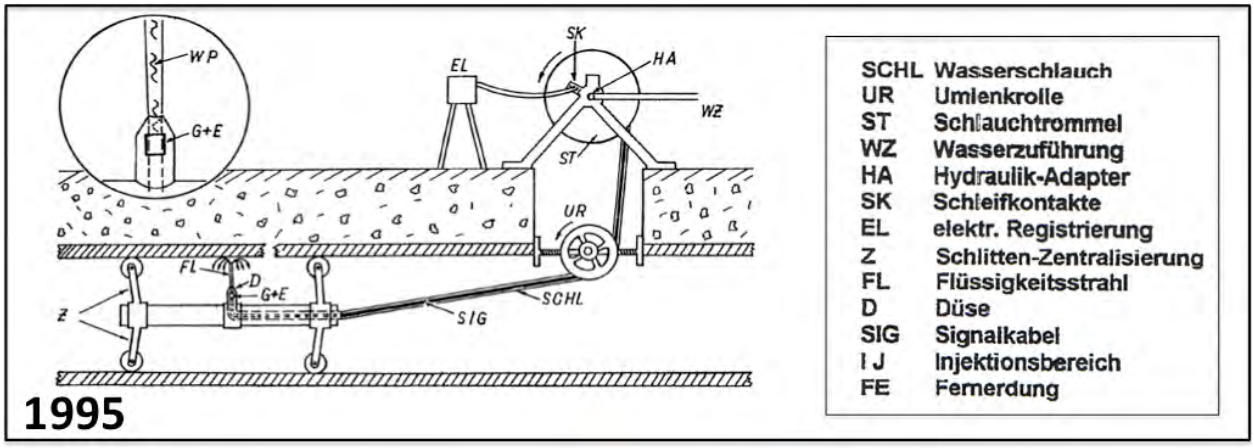
Start-up companies, in contrast, pursue "innovation" as their whole business; developing products outside of large company bureaucracies, oftentimes creating breakthrough products that utilize new technologies or that may be disruptive to longstanding products. The use of distributed optical fiber sensors, pressurized flood grouting, adhesion-based epoxy liners, and acoustic sensors are all example of emerging technologies from nimble new entrants.

Case Study: Electro Scan, Twenty Years of Product Evolution Leading to the 7th Edition

Development of a new condition assessment method, known as Electro Scan, scheduled for publication as part of the upcoming 7th Edition of the OPERATION AND MAINTENACE OF WASTEWATER COLLECTION SYSTEMS, Volume 1, began its journey in the 1990s. Originally introduced in 1995 as a German government-funded research project and later

abandoned after commercial prototypes were unable to deliver consistent results, software and hardware intellectual property were acquired in 2011. Soon after the product was re-engineered to be an add-on accessory to traditional CCTV trucks, utilizing existing cable, reel and power.

Figure 12.Electro Scan Product Diagram, 1995.



Electro scanning is carried out by applying an electrical potential (voltage) between an electrode (probe) released inside an electrically nonconductive pipe (e.g. asbestos cement, brick, clay, plastic, reinforced concrete, liners, etc.) and a grounding electrode on the surface, which is usually a metal stake pushed into the ground or attached to close by metal pole.

CCTV has been a dependable dry weather visual assessment tool guided by a defect identification guidelines governed by NASSCO's PACP standards. In contrast, electro scan represents the first tool capable of assessing pipes in wet weather conditions, often finding defects not found by visual techniques. Water in a pipe is at a level that ensures that the pipe is full surrounding its defect probe location. Providing there are no defects or leaks in a pipe, electric current is prevented from flowing from inside a pipe to outside ground (i.e. no pathway linking the inside of a pipe to ground); however, if there are any defects that a pathway between the electro scan probe (inside the pipe) and ground stake (on the surface), the electrical resistance of the current path can accurately identify (i.e. height of defect current, including start and end), locate, (i.e. within .04 inches or 1cm), quickly assess (i.e. 45-60ft per minute), and measure (i.e. GPM or LPS) individual and total sewer main defect flows within ± 40% accuracy.

After completing hundreds of thousands of linear feet of pipe for different diameters, pipe types, and conditions, electro scan was also found to be superior to finding defects in post-rehabilitation lining projects including the ability to detect cracks, defective joints, faulty service connections, undetected punctures, over-cooked and defective liners.

In 2006, the electro scan process was awarded ASTM standard F2550-06, Standard Practice for Locating Leaks in Sewer Pipes Using Electro Scan - - the Variation of Electric Current Flow Through the Pipe Wall. Following over 100 projects conducted in the United States, England, Japan, New Zealand, Australia, and Japan, electro scan's standard was expanded to recommend pre- and post-rehabilitation assessments, as recently published in ASTM F2550-13, Standard Practice for Locating Leaks in Sewer Pipes By Measuring the Variation of Electric Current Flow Through the Pipe Wall.

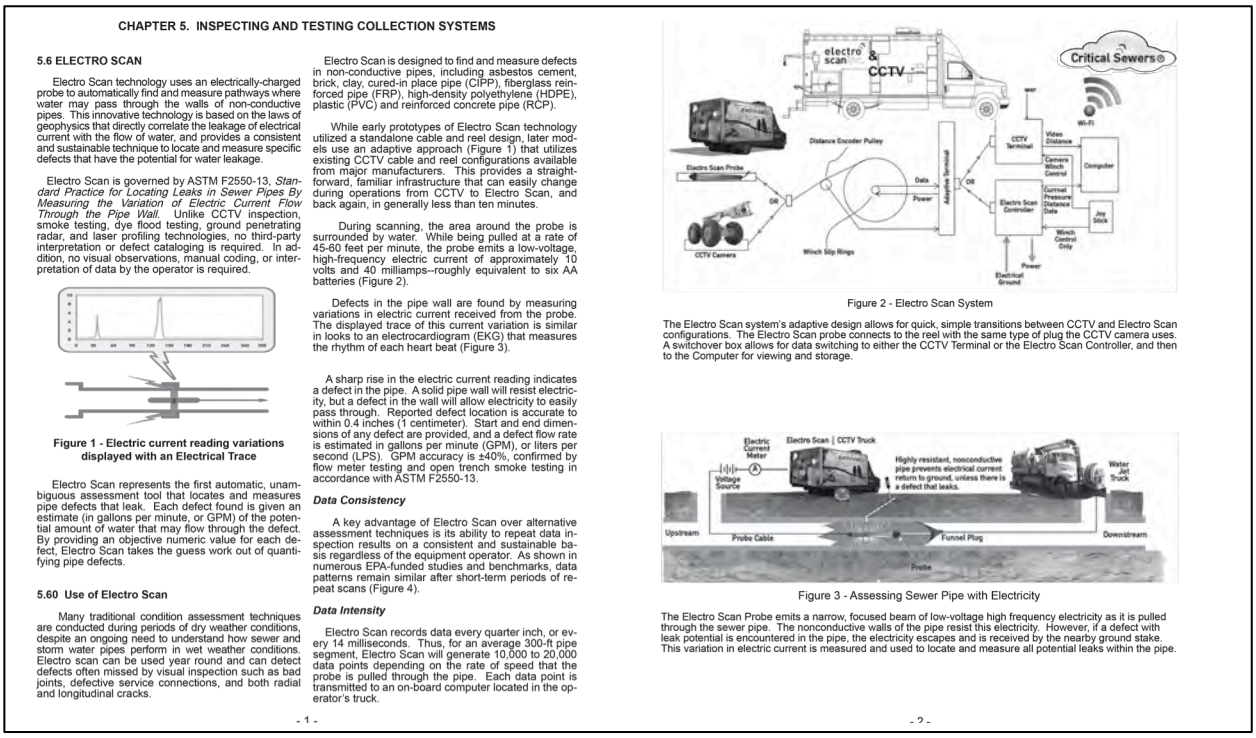
Table 5. Chronology of Adding a New Best Practise to O&M Manual.

1995	First German Patents Filed, based on government research and private company funding.
2001	IKT and Prof. Dr.-Ing. Stein & Partner GmbH, Bochum benchmark study and Institute for Construction Machinery and Constructional Work, RWTH Aachen: Tightness tests using the Sewer probe AMS4S20, research report, May 2001.
2003	First U.S. prototypes of FELL-21 and FELL-41 developed by Robert Harris.
2004	WERF – An Examination of Innovative Methods Used in the Inspection of Wastewater Systems 5.1.5.1 Focused Electrode Leak Location System (FELL-41) published.
2006	Multiple papers published & presented at ASCE Pipelines Conference. ASTM F2550-06 – Approved.
2009	Condition Assessment of Wastewater Collection Systems EPA/600/R-09/049, 4.3.1 Electrical Leak Location Method, published.
2010	State of Technology for Rehabilitation of Wastewater Collection Systems, EPA/600R-10/078, published, including section on Electro Scan technology.
2011	US EPA Field Demonstration of Condition Assessment Technologies for Wastewater Collection Systems, Kansas City, MO. First published benchmarking of CCTV and Electro Scan.
2012	US EPA/WERF Sewer Lateral Field Assessment Project, Milwaukee, WI. First commercial projects in the U.S., New Zealand and the United Kingdom. Commercial product availability for CCTV trucks. "Path of Least Resistance," Technology Test Drive, Municipal Water & Sewer Magazine, Dec. 2012.
2013	Over 100 U.S. projects completed. ASTM F2550-13 – Approved. "Adding Another Layer," Trenchless Technology magazine, Feb 2013. Selected Wastewater Collection Industry Awards: NASTT/No-Dig Award – Best New Product, WEF - Best Innovative Technology Award, New Economy Magazine - Best CleanTech for Water & Sewer, South West Water, England – PURE Award. First invitation to draft chapter on Electro Scan.
2014	Chapter outline, development, editorial review, and printing of 7th Edition, OPERATIONS AND MAINTENANCE OF WASTEWATER COLLECTION SYSTEMS.

In November 2013, Ken Kerri invited representatives of Electro Scan Inc. to contribute a new chapter to the upcoming Seventh Edition of the manual. In use by dozens of wastewater collection systems, and gaining acceptance with operators, meetings were scheduled in late 2013 and early 2014 to outline general requirements, content, and writing style that would guide chapter development. Beginning with the exchange of multiple text-based draft documents,

further drafts included diagrams, site photographs, and tables, leading to a pre-press chapter to be reviewed by other editors.

Figure 13. Inaugural Draft Chapter Introducing Electro Scan.



CHAPTER 5. INSPECTING AND TESTING COLLECTION SYSTEMS

5.6 ELECTRO SCAN

Electro Scan technology uses an electrically-charged probe to automatically find and measure pathways where water may pass through the walls of non-conductive pipes. This innovative technology is based on the laws of geophysics that directly correlate the leakage of electrical current with the flow of water, and provides a consistent and sustainable technique to locate and measure specific defects that have the potential for water leakage.

Electro Scan is governed by ASTM F2550-13, *Standard Practice for Locating Leaks in Sewer Pipes By Measuring the Variation of Electric Current Flow Through the Pipe Wall.* Unlike CCTV inspection, smoke testing, dye flood testing, ground penetrating radar, and laser profiling technologies, no third-party interpretation or defect cataloging is required. In addition, no visual observations, manual coding, or interpretation of data by the operator is required.

Figure 1 - Electric current reading variations displayed with an Electrical Trace

Electro Scan represents the first automatic, unambiguous assessment tool that locates and measures pipe defects that leak. Each defect found is given an estimate (in gallons per minute, or GPM) of the potential amount of water that may flow through the defect. By providing an objective numeric value for each defect, Electro Scan takes the guess work out of quantifying pipe defects.

5.60 Use of Electro Scan

Many traditional condition assessment techniques are conducted during periods of dry weather conditions, despite an ongoing need to understand how sewer and storm water pipes perform in wet weather conditions. Electro scan can be used year round and can detect defects often missed by visual inspection such as bad joints, defective service connections, and both radial and longitudinal cracks.

Electro Scan is designed to find and measure defects in non-conductive pipes, including asbestos cement, brick, clay, cured-in place pipe (CIPP), fiberglass reinforced pipe (FRP), high-density polyethylene (HDPE), plastic (PVC) and reinforced concrete pipe (RCP).

While early prototypes of Electro Scan technology utilized a standalone cable and reel design, later models use an adaptive approach (Figure 1) that utilizes existing CCTV cable and reel configurations available from major manufacturers. This provides a straightforward, familiar infrastructure that can easily change during operations from CCTV to Electro Scan, and back again, in generally less than ten minutes.

During scanning, the area around the probe is surrounded by water. While being pulled at a rate of 45-60 feet per minute, the probe emits a low-voltage, high-frequency electric current of approximately 10 volts and 40 milliamps--roughly equivalent to six AA batteries (Figure 2).

Defects in the pipe wall are found by measuring variations in electric current received from the probe. The displayed trace of this current variation is similar in looks to an electrocardiogram (EKG) that measures the rhythm of each heart beat (Figure 3).

A sharp rise in the electric current reading indicates a defect in the pipe. A solid pipe wall will resist electricity, but a defect in the wall will allow electricity to easily pass through. Reported defect location is accurate to within 0.4 inches (1 centimeter). Start and end dimensions of any defect are provided, and a defect flow rate is estimated in gallons per minute (GPM), or liters per second (LPS). GPM accuracy is ±40%, confirmed by flow meter testing and open trench smoke testing in accordance with ASTM F2550-13.

Data Consistency

A key advantage of Electro Scan over alternative assessment techniques is its ability to repeat data inspection results on a consistent and sustainable basis regardless of the equipment operator. As shown in numerous EPA-funded studies and benchmarks, data patterns remain similar after short-term periods of repeat scans (Figure 4).

Data Intensity

Electro Scan records data every quarter inch, or every 14 milliseconds. Thus, for an average 300-ft pipe segment, Electro Scan will generate 10,000 to 20,000 data points depending on the rate of speed that the probe is pulled through the pipe. Each data point is transmitted to an on-board computer located in the operator's truck.

- 1 -

Figure 2 - Electro Scan System

The Electro Scan system's adaptive design allows for quick, simple transitions between CCTV and Electro Scan configurations. The Electro Scan probe connects to the reel with the same type of plug the CCTV camera uses. A switchover box allows for data switching to either the CCTV Terminal or the Electro Scan Controller, and then to the Computer for viewing and storage.

Figure 3 - Assessing Sewer Pipe with Electricity

The Electro Scan Probe emits a narrow, focused beam of low-voltage high frequency electricity as it is pulled through the sewer pipe. The nonconductive walls of the pipe resist this electricity. However, if a defect with leak potential is encountered in the pipe, the electricity escapes and is received by the nearby ground stake. This variation in electric current is measured and used to locate and measure all potential leaks within the pipe.

- 2 -

Figure 14. Sewers, Plus Electricity.

Editorial Process

The Editorial Staff at the Office of Water Programs, California State University, Sacramento, has become an integral part of creating previously published and current editions of OPERATION AND MAINTENANCE OF WASTEWATER COLLECTION SYSTEMS. The Editorial Staff must ensure the delivery of a cohesive, well-written, and relevant document that must address and represent the state of the collection industry. This section will discuss the final stages of managing the process.

Throughout the history of developing its manuals, the Office of Water Programs at California State University, Sacramento, has been the focal point for keeping operator training manuals current, including the editing of materials and preparation of manuscripts for printing, correction of printer's proofs, coordinating production of the manual, overseeing all administrative details, sales, shipments, and deliveries.

Lessons Learned

Many lessons have been learned since the publication of the first manual in 1976 and issuance of the first certificate of course completion in 1977.

Figure 5
Certificate of Completion – Woodie Mark Muirhead.

Many stories have emerged during the course of the home study course of distinguished students. But, none as inspiring as then a letter once received from a person incarcerated at a State Prison. Damaged manuals are routinely provided free of charge to prisoners, with one such manual provided to a young man that was a self-described former drug-addicted, armed robber, that wrote a letter to Ken Kerri asking if someone like him could ever hope to become a wastewater collection operator. Completing the self-study course and paroled from prison, that student is now a manager of a leading wastewater utility.

"If you study our manuals, you can manage a big utility," states Ken Kerri.

Given the risk of obsoleses that may occur as soon as the latest edition is sent to the publisher, the Office of Water Programs at California State University, Sacramento, begins formulating the next edition as soon as the previous addition is completed; continuing its ongoing cycle of assessment, review, modification, expansion, deletions, and corrections, to keep abreast of and implement new advancements driven by the wastewater collection profession.

References

ABC, "Wastewater Collection System Personnel Examination Questions, Harris Seidel, ABC, Executive Secretary, Ames, IA, 1980

ASTM F2550-06, Standard Practice for Locating Leaks in Sewer Pipes Using Electro Scan - - the Variation of Electric Current Flow Through the Pipe Wall. ASTM Committee F36 on Technology and Underground Utilities and is the direct responsibility of Subcommittee F36.20 on Inspection and Renewal of Water and Wastewater Infrastructure, 2006

ASTM F2550-13, Standard Practice for Locating Leaks in Sewer Pipes By Measuring the Variation of Electric Current Flow Through the Pipe Wall, ASTM Committee F36 on Technology and Underground Utilities and is the direct responsibility of Subcommittee F36.20 on Inspection and Renewal of Water and Wastewater Infrastructure, 2013

"Electro Scanning Technology Adds Another Layer of Inspection." Sharon M. Bueno, Trenchless Technology Magazine, February 2013.

Interviews, Kenneth D. Kerri, March 2014.

OPERATIONS AND MAINTENANCE OF WASTEWATER COLLECTION SYSTEMS, VOLUME 1 AND 2, Edition 1-7. California State University, Sacramento, 6000 J Street, Sacramento, CA 95819-6025, 1976-2013.

OPERATIONS AND MAINTENANCE OF WASTEWATER COLLECTION SYSTEMS, VOLUME 1, 1976, Preface to the First and Second Editions, Kenneth D. Kerri, John Brady, 1976.

Wastewater Collection System Operator Certification Studybook, Donald S. Pottle and James Courchaiine, Environmental Educational Services, Concord, MA, November 1982

USEPA Sewer Electro Scan Field Demonstration Revisited, Terry Moy, Charles G. Wilmut, and Robert J. Harris, September 2012.