Meeting the Demands of the Future: Revolutionizing Your Workflows to Achieve More With Less

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ABSTRACT
As is often the case for many business operations within the knowledge work industry at large, workflows are generally understood by the individuals managing and/or performing the work, but typically aren't well defined, formally published, or efficiently transferrable to an uninitiated party. In relying on nebulous workflows that, for the most part, exist within the minds of a few individuals, performing what should otherwise be efficient workflows due to their repetitive nature ends up becoming an exercise in loosely "reinventing the wheel" each time the same workflows are executed for new projects. Performing work in this manner leads to significant inefficiencies, overwork on the part of those tasked with managing projects, and lack of consistency and quality of the product. This paper discusses how The Metropolitan Sewer District of Greater Cincinnati's (MSDGC) Modeling Group overcame these exact challenges by transforming their internal business operations.

KEYWORDS
Workflow optimization, business operations, staff empowerment, efficiency, automation, quality control, hydraulic modeling, version control, data centralization, standardization

INTRODUCTION

The pace of work, amount of data, and number of tasks that a knowledge worker must manage has increased significantly within the last decade. The reasons for this are not the focus of this paper, but a speculative assumption may be that this is the result of a culmination of factors – a growing gap between the labor demand and labor supply, recent advances in computing power, and the advent of Artificial Intelligence (AI), which may soon lead to the commoditization of many industries – to name a few.

Downstream of these factors are a quickly shifting landscape that is the Knowledge Work industry at large. In his book *Deep Work*, author Cal Newport posits that there is a New Economy coming where success is based on your ability to focus on providing value, and that this will require knowledge workers to produce at an elite level in terms of both speed and quality (2016). Currently, this is (generally speaking) entirely at odds with how most knowledge work is performed today, in that to produce at this elite level, knowledge workers must have the opportunity to focus.

As Cal Newport rightly observes in his book *A World Without Email,* the current state of the knowledge work industry is analogous to the automobile industry prior to Henry Ford. Rather than seeking to define and improve existing workflows, knowledge workers instead default to execution of tasks in an ad hoc and unstructured manner, in much the same way cars were assembled prior to the assembly line. Instead of following and executing a defined workflow, knowledge workers at the staff level are expected to remain in constant contact with Senior Project Managers to provide constant status updates. This leads to perpetual interruption on the part of staff who are performing the work – meeting requests, messages, emails, video calls – and leaves little time for focus or *actually completing* the work. (2021)

Newport gives this concept – constant interruption and perpetual coordination amongst all team members at all times – a name: the hyperactive hive mind. Newport states: “The future of work is increasingly cognitive. This means that the sooner we take seriously how human brains actually function, and seek out strategies that best complement these realities, the sooner we’ll realize that the hyperactive hive mind, though convenient, is a disastrously ineffective way to organize our efforts.” (2021)

This isn’t to say that no effort has been made to augment how knowledge work is performed. New tools are constantly being developed – email and messenger application enhancements; digital calendars and task management systems; software for scheduling, proposal tracking, and applicant tracking; and low-code/no-code workflow automation applications – to name just a few.

However, these “advancements” are most often received and utilized in the same manner as the analogy provided in Michael Simmons’ article “The threat to knowledge workers is not AI or automation. It’s their horrifying lack of productivity”. In the article’s analogy, a worker is tasked with transporting a pile of bricks from one location to another. Instead of making several trips carrying the bricks by hand (as he had always been doing), the worker is given a wheelbarrow. The worker then fills the wheelbarrow with bricks, picks up the wheelbarrow, and carries the wheelbarrow full of bricks. Meaning, knowledge workers are given new tools all the time, but rarely is there ever effort to figure out how best to utilize those tools most efficiently within the context of already existing workflows, often resulting in marginal improvements at best, or a decrease in efficiency at worst. (2023)

Simmons points out that “[v]ery few people set aside time for improving, which results in the following symptoms:

- We underestimate our potential to improve
- We overestimate how productive we are day-to-day
- We underestimate how unproductive we are day-to-day
- We underestimate the incredible power of continuous improvement because compounding is hard to understand
- We don’t understand what it means to be deliberate and systematic about improvement, so we settle” (2023)

Specifically, within the engineering industry, exacerbating this issue is the gap between labor demand and labor supply, which is expected to grow exponentially over the coming years, as documented in the Engineering Change Lab Summit 14 report. Drilling down further within the engineering industry is the even smaller subset of Water Resources Engineering professionals. The niche specialty of hydraulic modeling is a specialty continually struggling to backfill and expand its talent pool to meet the ever-increasing demand for complex hydraulic modeling commensurate with the exponential advances in computing power.

In the face of these issues, the Metropolitan Sewer District of Greater Cincinnati's (MSDGC) Modeling Group completed an extensive overhaul of their internal workflows to address these challenges head on. In doing so, they were able to revolutionize their model update and management procedures in a way that not only increased the efficiency with which work was completed, but also achieved a significant increase in the quality and consistency of their model updates that they oversee. This paper will provide detail of what they did to accomplish this, to provide context and a framework around how to revolutionize workflows, in general.

BACKGROUND

MSDGC maintains numerous different models of their sewer system representing the various service areas. With ongoing improvements to the system and continuous flow monitoring, maintenance of MSDGC's models is an extremely dynamic process that is continually in a state of change. These demands often led to strain on the part of the staff, as well as presented challenges for how to effectively manage the constant changes to the models.

The Issues

MSDGC's prior modeling processes were focused on individual project area calibrations that may or may not be incorporated into the overall system models. The calibration process and documentation process followed a general pattern of consultant calibration with development of a calibration report. The report, the model input file, and the meter calibrations would be reviewed with a cycle of calibration refinement and updating the reporting. Within this process was the flow of information up the consultant hierarchy, across to MSDGC, down MSDGC for review, back up MSDGC for comment, then back through the consultant for response.

All of this resulted in continuous iterations of back-and-forth between MSDGC's Modeling Group and the Consultants. These iterations often led to delays in approvals affecting the entire project, and left the staff overburdened with constant review meetings.

What's more, due to Consultants' struggles to follow MSDGC's standards and maintaining a patchwork of documentation of updates that were made and the justification for those updates, the quality of the models was routinely called into question by stakeholders for the duration of the project. This would often lead to numerous meetings and quality assurance/quality control (QA/QC) reviews amongst Senior level members of the project teams to further belabor critical updates to the model that had already been reviewed previously, costing valuable time and money.

All these issues came to a head when MSDGC was faced with undertaking the largest model calibration effort in its history. The need for a clear process grew out of the size of the calibration effort (180 meters), the number of consultants (five prime and several sub consultants), and the fixed time frame. The goal of the calibration was to develop a set of combined sewer models for past and current hydrology and hydraulics that demonstrate MSDGC had effectively spent over a billion dollars to reduce sewer overflows in compliance with a federal Consent Decree. A fixed date required delivery of a report discussing the calibration process and model results to document the impact of the billion dollars of construction on sewer overflows.

Given the number of meters to be calibrated against, the number of consultants, and the limited time frame available to meet the consent decree requirements, existing methods for evaluating and managing model updates would have been ineffective for many reasons. Because of this, MSDGC and the consultants began to develop a streamlined process to submit and review calibrations with a more direct flow of information in both directions.

METHODOLOGY

MSDGC developed a system for managing their models that streamlined the model update process, implemented a higher standard of quality, and automated much of the workflow involved in managing numerous model updates at the same time.

Increasing Efficiency

Defining Workflows

The first step MSDGC took in improving the model management practices involved the development of flowcharts that clearly defined the process of updating a model from start to finish. Shown in **Figure 1** is an example of one of these flow charts that is to be followed for a Standard Modeling Project (MSDGC ultimately developed multiple flowcharts for the different types of models they maintain).

While this may not initially seem like a revolutionary concept (development of a flowchart), the extent to which this flowchart (and all the others) was developed was indeed significant. Upon closer inspection, a user is provided with information on the model version progression, which section of the Modeling Guidelines to review prior to each update milestone to adhere to MSDGC's standards, and exactly what form is to be submitted when, by whom.

Further, within each form, explicit detail on the items that must be compiled and submitted for review, is provided. An excerpt from one of the submittal forms is shown in **Figure 2** to illustrate this.

Again, this may not appear to be revolutionary at first blush. However, what is so effective about this approach, and most often lacking from attempts to formalize workflows, is the detail with which the required steps and actions that each party must take to complete the model review process has been laid bare.

In his book *Getting Things Done*, author David Allen explains that most planning processes get right up to the point of actually determining what specific actions need to be taken. That's because brainstorming high-level concepts about what needs to be done is the easy part. Breaking those concepts down into appropriately sized components, and then subsequently assigning explicit actions to be taken to complete each component is not as easy. In other words – it requires a lot of hard thought, and human tendency is to avoid this. Instead, what's more preferred is to utilize what Allen defines as the "Reactive Planning Model," which is just as it sounds – reacting to issues as they come up is preferred, as this doesn't require hard thinking. (2015)

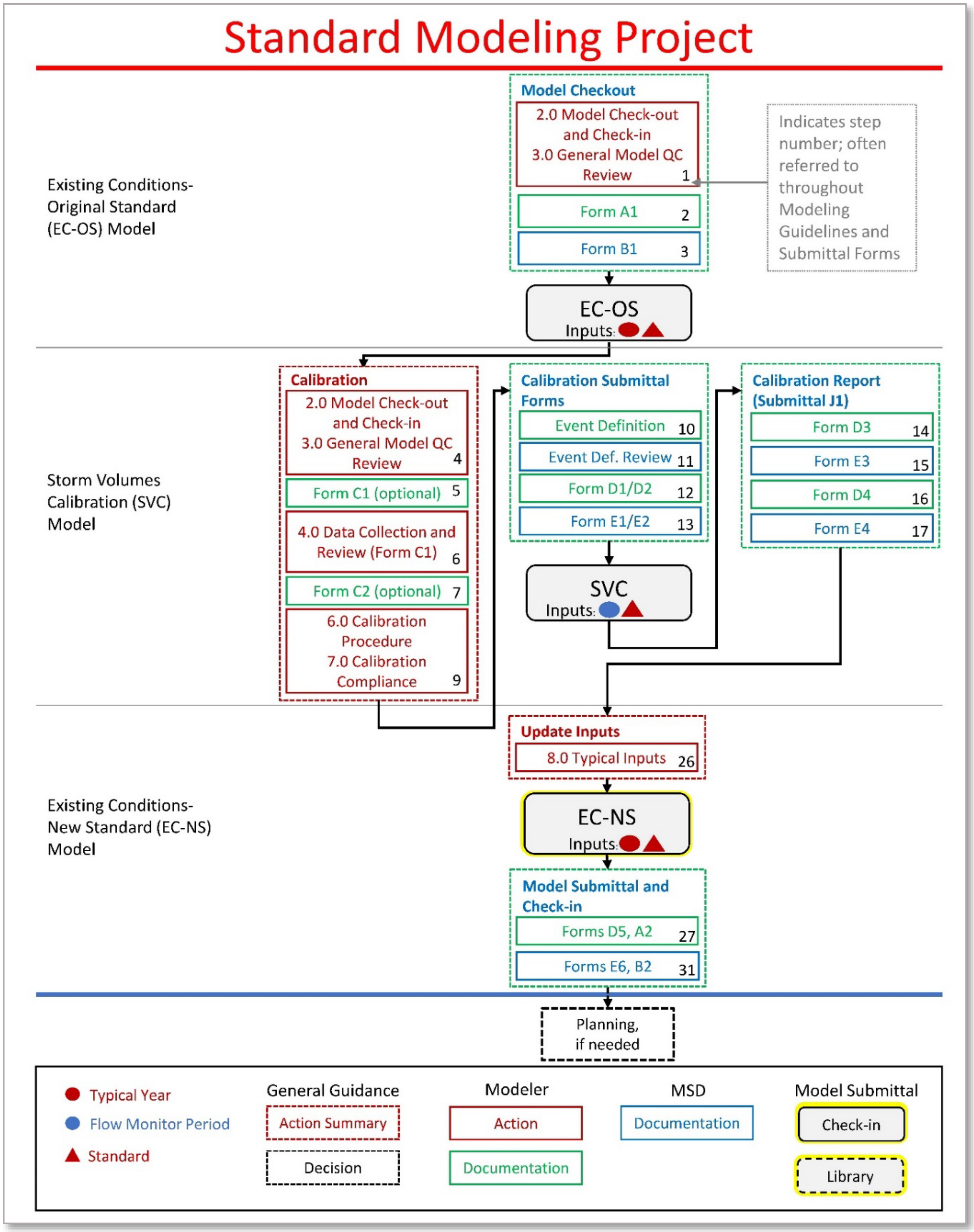

Figure 1 Example Flowchart for a Standard Modeling Project

Detailed Check for Modeling Errors
Submittal Form

Project Name: ____

Entity Submitting for Review: __________________________________

Date of Submittal: ____

D2.0 GENERAL MODEL QA/QC

NOTE: refer to **Volume II Section 3.0** for guidance and explanation on performing these General Model QA/QC checks.

Model Audits

Refer to **Volume II Section 3.0** for guidance.

- ☐ Orphan Detection
- ☐ Conduit Slope Screening
- ☐ Attribute Validation
- ☐ Audit Results Table in which audit flags are reviewed, summarized, and categorized as being either “real” or a “non-issue.”

Table D2-1. Example Audit Results Table

Model Element	Audit Flag	Real or Non-issue	Explanation

☐ Hydraulic profile review has been conducted to check for invert errors (refer to **Volume II Section 3.1.1** for guidance)

☐ Subcatchment connectivity review to check for misconnected basins (refer to **Volume II Section VOLUME II.3.1.2** for guidance)

Dry Conduits

Refer to **Volume II Section 3.3** for guidance.

- ☐ No dry conduits
- ☐ Dry conduits which cannot be removed – these conduits include cross-connection conduits, SSO/CSO outfalls, and conduits with flows loaded upstream for the Typical Year.
- ☐ Dry conduits which can be removed – review and provide information supporting removal

Table D2-2. Example Dry Conduit Table

Conduit ID	Remove/Do Not Remove	Explanation

Figure 2 Excerpt From Submittal Forms Required as Part of the Model Review Process

Facilitating Workflows with Centralized Automation and Dashboarding
Typically, when workflows are defined – whether for model review, or knowledge work processes in general – they "live" within a document that is shared with the project team. The workflow is then manually enforced by those responsible for managing the project, which generally involves frequent check-ins with all members of the project team (hyperactive hive mind), as well as Senior level staff (costly time and money), to ensure that the process is being followed correctly.

MSDGC took a different approach, and implemented their workflows within a centralized database, FlowFinity (www.flowfinity.com). This allowed the Modeling Group to mirror every step of the Model Review Process within FlowFinity, such that there was a single source of information and record for every submittal item throughout the process. An example of this is provided in **Figure 3.**

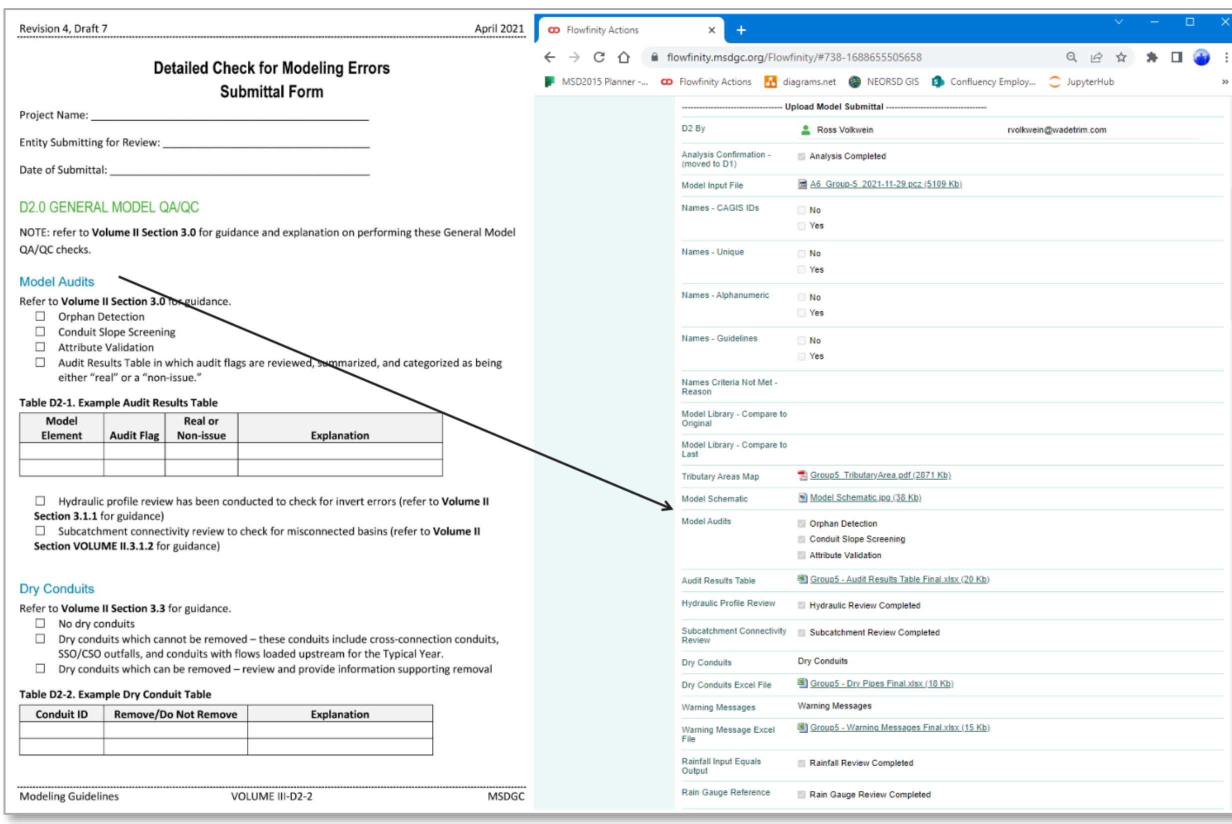

Figure 3 Excerpt of Submittal Forms and Cross-Correlation With FlowFinity Database

Further, the Modeling Group then linked the review process steps on the backend of the database to automate the facilitation of the entire process. For example, once a staff engineer completed their upload of submittal items, the designated reviewer would receive an automated prompt informing them the items were ready for review. Following the review, the Modeling Group would be notified for final approval, and so on. Additionally, the status of every project indicating where in the review process it currently stands, and who is responsible for advancing the review to the next state, was all summarized and available to anyone to view within a centralized dashboard. This automated facilitation was implemented for the entire process from start to finish, for all workflows.

What made this approach to managing their review process so effective was the fact that FlowFinity offered a no-code solution for automating MSDGC's workflows on the backend of the database, as well as offering a centralized dashboard, and Graphic User Interface that allowed for intuitive use. Because of this, MSDGC was able to drive adoption of FlowFinity, thus driving adoption of their explicit workflows that they had already clearly defined.

Further, because each item and requirement were so explicitly defined, this empowered users at the staff level to be completely accountable for their own work, rather than relying completely on Senior level staff, and subsequently defaulting to a Reactive Planning Model approach. This resulted in finding and fixing more errors further down on the staff profile, much earlier on in the project, which mitigated the propagation of those errors later in the process, thus reducing overall time and cost.

Another reason this approach worked so well was due to the automated nature with which the work was facilitated. Newport states that "[t]he premise on which this effectiveness is built is that communicating about tasks often gets in the way of executing them — the more you can off-load this communication from the cognitive space of your staff, the more effective they become at actually getting things done." (2021) Not only does this allow staff the opportunity to focus more clearly, but this also alleviated some of the workload that would have normally been required of a Project Manager to manually advance the entire time through the review process.

This concept is illustrated schematically in **Figure 4** and **Figure 5**. Shown in **Figure 4** is the blunt workflow that is most often the default within knowledge work, in that the Project Manager (Person 1) must manually prompt all staff to drive a task to completion. Contrast this with the automated and clearly defined workflow in **Figure 4** where Person 1 only initiates a process (workflow), which is then pushed into an already defined System (model flow charts; and FlowFinity) that automatically prompts each person without the need for constant prompting from Person 1 (hyperactive hive mind). Further, because every required item and action by each person has been clearly and explicitly defined, staff already know what they need to do when they are prompted (avoiding the Reactive Planning Model approach).

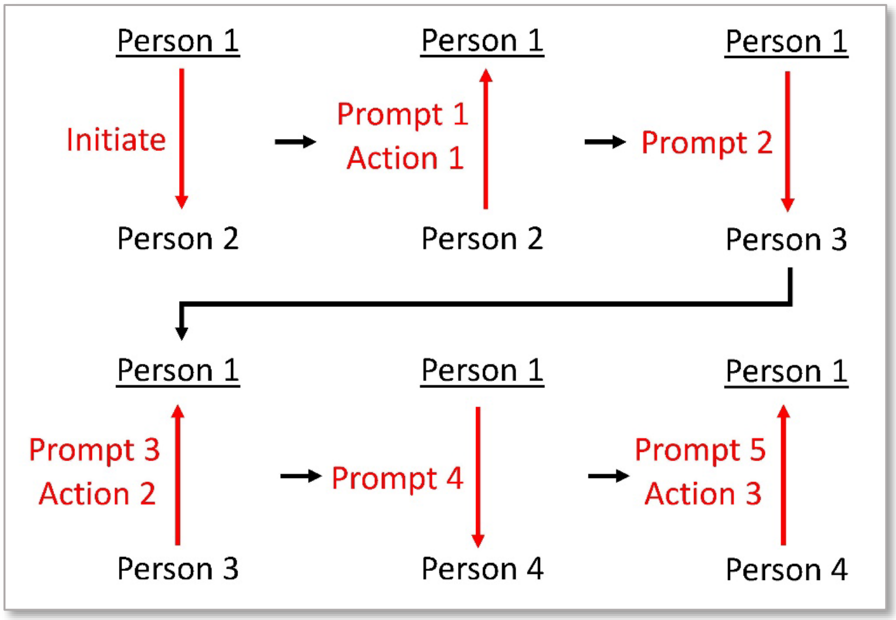

Figure 4 Default Blunt Workflow Requiring Significant Effort To Manually Advance Tasks To Completion

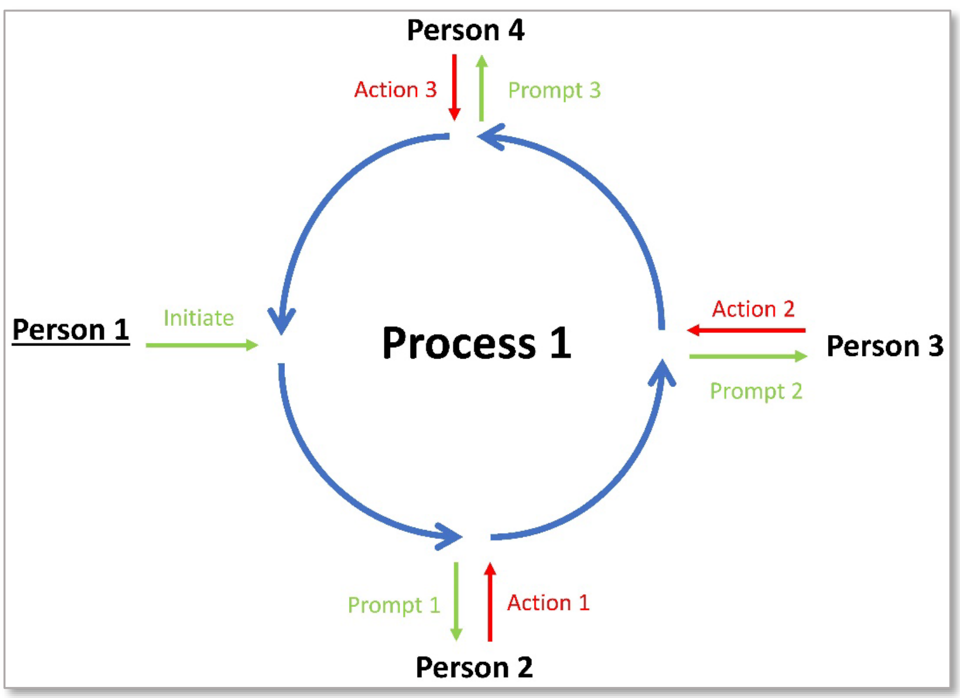

Figure 5 Automated Facilitation of Clearly Defined Workflows That Mitigate Workload Needed To Complete Task

Quality Assurance and Quality Control

As Simmons points out, a concept that is key to increasing productivity is “having a standard for quality that [is] tracked and upheld”. The obvious downstream benefit of this being that significant gains in quality are also achieved, which is a claim that can be backed up by Taiichi Ohno, the creator of the Toyota Production System, when he says that “[w]here there is no standard, there can be no continuous improvement.” (2023).

To tackle this challenge, the Modeling Group performed a comprehensive rewrite of their Modeling Guidelines. This document was aligned with their workflow flow charts that were previously discussed and was complemented by numerous evaluation metrics and tools that were developed to ensure enforcement and consistency.

Having a Clear Standard

While there were innumerable aspects (and sub-aspects, and sub-sub-aspects, and…) to the model update process for which the Modeling Group developed quality controls, this portion of the paper will focus (at a high level) on the standards that were developed for one specific topic – model calibration. While this will only focus on one specific area of a highly niche specialty within water resources engineering, note that the approach for defining standards, and the benefits derived from doing so, can be extrapolated upon and applied to any process. This specific example is only being used to illustrate this concept within the larger context of improving quality within any type of knowledge work for any type of specialty.

The issue that the Modeling Group was faced with on this specific topic was not unlike the same issue that anyone in modeling has – inconsistent and poor fit with observed data. The prevailing guidance for any model calibration endeavor was always to (in so many words) match peak flow and total volume for a number of events. However, what the Modeling Group found was that this didn’t provide enough granularity into exactly *how* to match peak flow and total volume. This brings up an important concept – *granularity*. In that, peak flow and total volume as metrics, don’t provide any (granularity, that is).

In the late 1800s, Fredrick Winslow Taylor devised a system for improving the efficiency with which manual labor was performed. Since that time, there has been a 50x increase in productivity within the manual labor industry. Part of his system for improving any process is to break it down into smaller and smaller detail, and then study how to improve each step at the granular level. (Simmons 2023)

MSDGC effectively utilized this same approach, with the intent of improving model fit. Improvement was achieved by first defining the components of the overall hydrograph, as shown in **Figure 6**. This step isn’t anything new, as the modeling industry understands these flow components, and this is where most comparative metrics are applied. The advancements came with the next step, in which the *Storm Flow* component was further broken down into even smaller components to provide much more *granularity* into how the models were fitting to different parts of the storm.

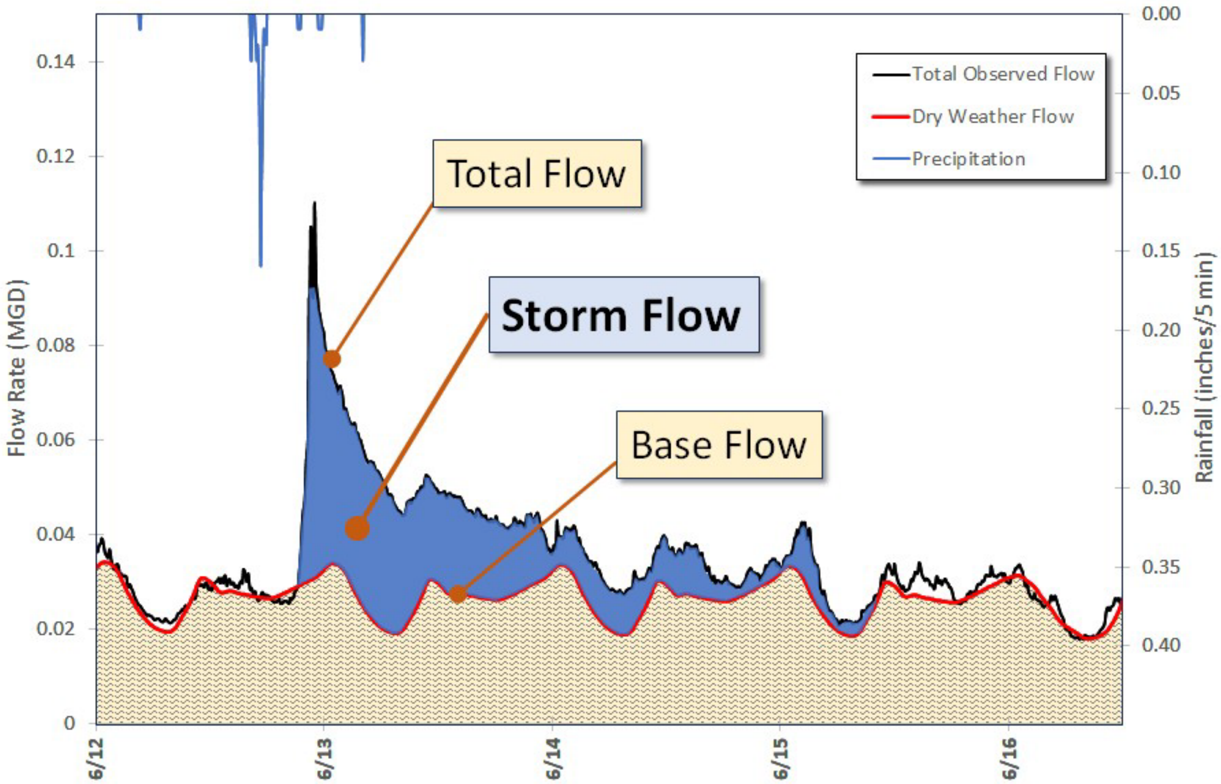

Figure 6 Defining the Different Overall Flow Components of a Hydrograph

MSDGC's model calibration approach focuses on the timeframes within wet weather events that will most impact the resulting model predictions (e.g., remaining overflow volume (ROV) and peak rate). The approach employs the use of multiple sub-events in lieu of the more typical approach of calibrating to just peak flow rate and total event volume. Each calibration event is sub-divided into three periods of time (sub-events) and calibration metrics are evaluated on the volumes within each sub-event. The sub-dividing approach evaluates three sub-event zones (depicted in **Figure 7**) for each event.

The following provides description of each sub-event duration and its purpose in model calibration:

- **Conveyance –** The shortest sub-event duration defines the peak flow conditions for an event. This period of the event represents the time at which the sewer conveyance capacities are most stressed. Calibrating to this portion of the hydrograph provides an increased accuracy when using the model for evaluating conveyance capacities of existing or proposed infrastructure. Conveyance is defined as $1/8^{th}$ of the event, with a minimum duration of three data points (15 minutes) and a maximum duration of one hour.
    - Conveyance: (15 minutes < 1/8 of Event < 60 minutes)
- **Overflow –** The Overflow sub-event duration defines the period at which the system capacity has been exceeded and overflows may be occurring. This duration is the critical feature of MSDGC's calibration approach and fundamentally enforces a proper shape to the resulting unit hydrograph. Calibrating to this portion of the hydrograph increases the

accuracy of predicting ROV and/or sizing storage-type infrastructure. Overflow is defined as ¼ of the event, with a minimum duration of four data points (20 minutes) and a maximum duration of four hours.

  - Overflow: (20 minutes < ¼ of Event < 240 minutes)

- **Treatment –** The sub-event duration is equal to 75% of the event duration. Calibrating to the treatment sub-event improves the accuracy of total volume conveyed to wastewater treatment. It has a minimum duration of 30 minutes.
  - Treatment: (30 minutes < 0.75 x Event)

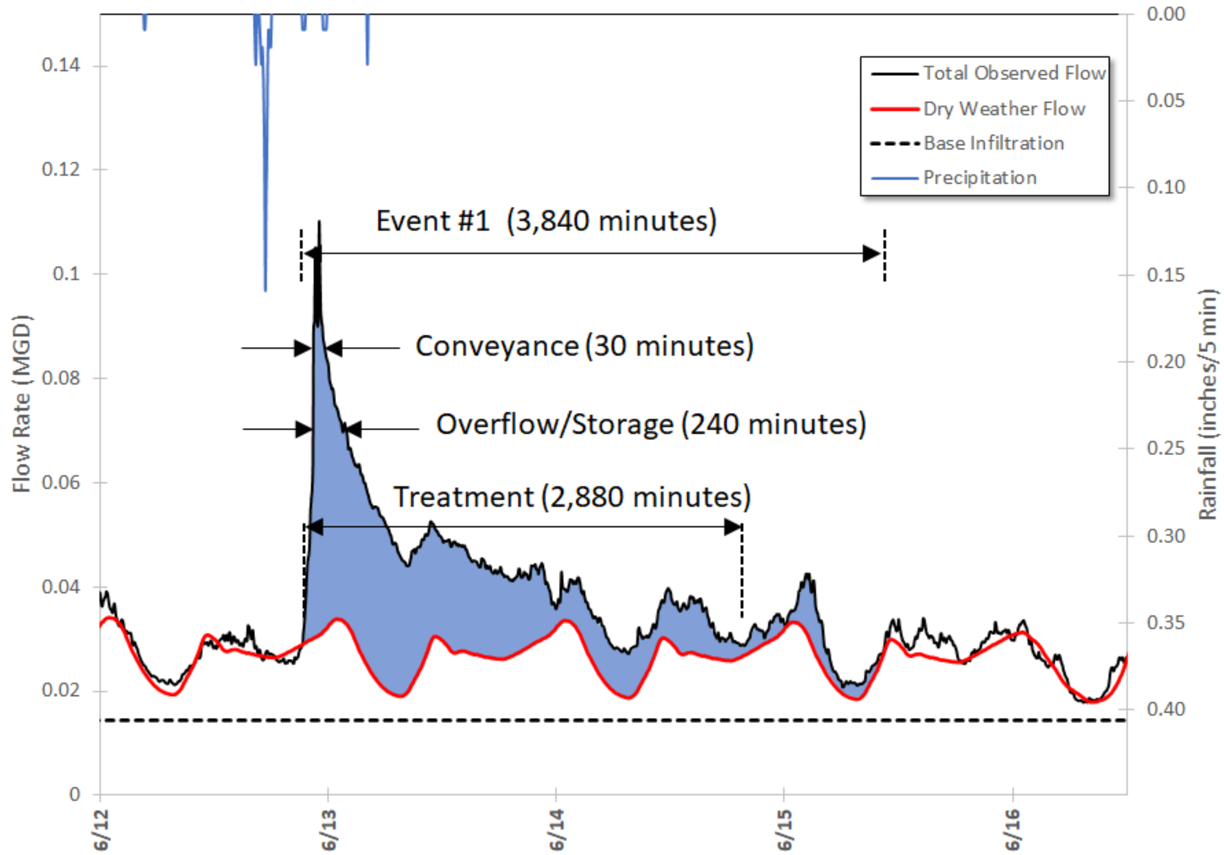

Figure 7 Defining in Granular Detail the Different Parts of the Storm Flow Component of a Hydrograph

While this summary of how MSDGC defined different parts of a storm is only one small aspect of a much larger set of definitions and metrics that MSDGC developed, it does provide a brief look into the process for breaking larger components down into smaller detail to evaluate each part individually. From there, MSDGC developed new metrics to evaluate the model's fit to *each granular component* of the hydrograph, rather than only comparing the total flow for the entire duration of the storm. MSDGC requires that the Model Storm Flow (MSF) accurately reflects the Observed Storm Flow (OSF). Storm Flow is that additional flow resulting from the rainfall in contrast to Total Flow which includes sanitary flow, groundwater intrusion, etc. In the collection system modeling industry, as a general practice, models are not checked for Goodness Of Fit

(GOF) to the Storm Flow but rather to the Total Flow. Thus, in defining metrics based on Storm Response, MSDGC is, *as far as we know*, unique.

Enforcing Standards
Any set of standards – no matter how comprehensive and effective they are – are only useful if there exists an effective mechanism for evaluating them, which thus facilitates their enforcement. *Because if you can't tell whether your standards are being followed, how will you ever be able to enforce them?*

Previously, and most commonly throughout the modeling industry, the process for evaluating a model's performance relied on generating numerous excel tables, graphs, and maps in a fairly piecemeal fashion, which led to an inefficient and scattered approach to evaluating models. Drafting of figures can be time consuming depending on the method and the amount of data to manage. Sometimes figures can be eliminated as unnecessary or can be generated using modeling or other visualization software. Additionally, each consultant had its own methods, tools, and formats so products delivered to MSDGC weren't consistent between consultants

When Fredrick Winslow Taylor was breaking down the steps for shoveling coal and stone into granular detail, he would systematically experiment with different approaches to shoveling to find the best way possible. Once found, he would standardize that approach across all workers. What he discovered was that different shovel sizes – one for coal, and one for stone – provided the optimal weight with which a worker could maximize their ability to shovel. And thus, different shovel sizes were established. (Simmons 2023) (*Shovel*) This is perhaps the first major advancement in shoveling technology since evidence of the existence of a shovel was thought to first be used during the Neolithic age 12,000 years ago, which at the time a "shovel" was thought to be fashioned from a large animal's scapula (shoulder blade). (*Shovel*)

We may just now be advancing past the "Neolithic age" of evaluating model results.

MSDGC has developed a calibration evaluation Tool ("the shovel" in this analogy) with standardized visualizations ("different shovel sizes") for each specific component of the flow hydrograph ("coal versus stone"). The Tool also applies the specialized metrics they had developed (discussed in previous section) to each part of the storm ("the Neolithic age to present-date"). A screenshot from one of the Calibration Tool's tabs is shown in **Figure 8**.

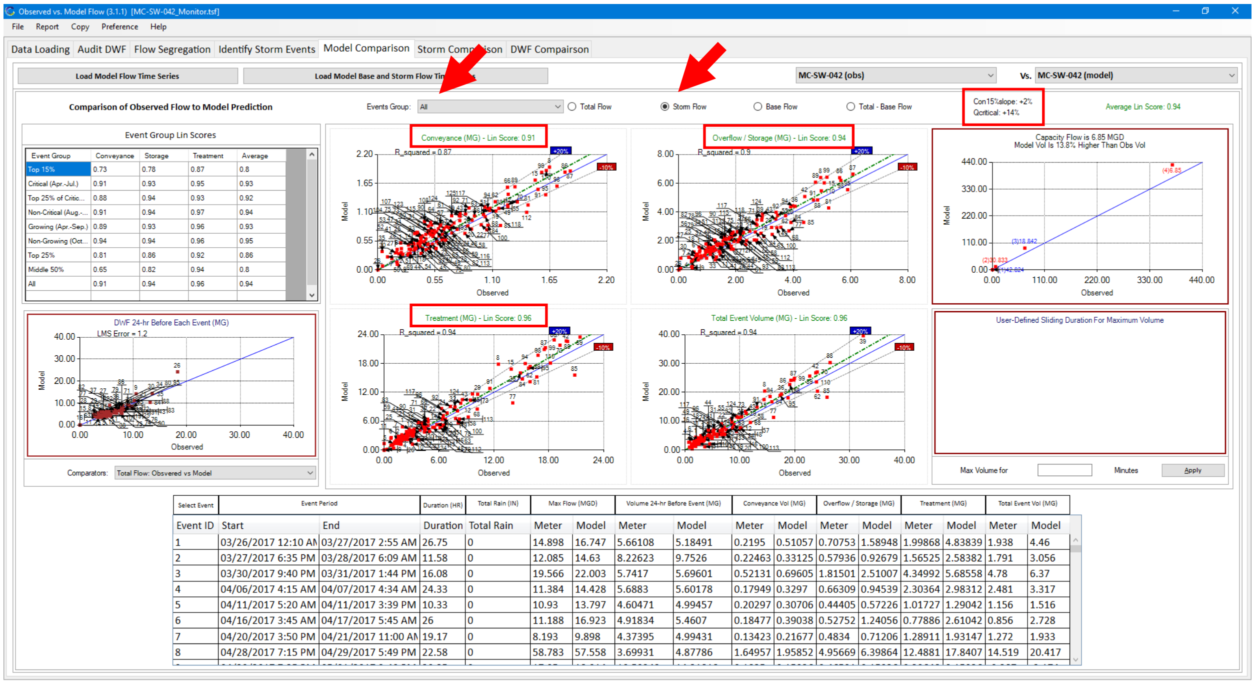

Figure 8 Screenshot From MSDGC's Calibration Tool That is Used To Evaluate All Model Calibrations in a Predetermined Standardized Fashion

In addition to this, they also developed a standardized set of output visualizations that result from their Model Archiving process (discussed in the next section).

Conforming Input from All Workflows

After development of the many different workflows, standards, evaluation metrics, and new Tools, MSDGC needed a way to make sure that all their changes were being captured and conformed appropriately. For context, MSDGC's collection system model is separated into seven model basins each with multiple versions including historical, existing and future planning conditions. The hydraulic model is an important tool for capital planning and the basis for MSDGC's regulatory compliance. As such, it is distributed both internally and externally to many different consultants all performing model updates concurrently. Hydraulic model updates can include calibration, new construction, survey updates and alternatives analysis for capital planning. Model updates are in all stages of completion (just starting to complete) by both internal and external modelers. Too often, the Modeling Group was faced with questions including, "What does this model include?" and "Is this the latest version?". The limited organization of the modeling components and the uncertainty of model versions and calibration status led to issues within the model files, updated project work was overwritten, project calibrations were not incorporated, or new construction was not represented. The project work to support Consent Decree compliance is so heavily reliant on the Hydraulic Model, a new workflow had to be developed to definitively answer the question "What is the quality of this model and what does it include?"

Generally speaking, this is a fairly common issue among all of Knowledge Work, in that there are so many inputs from so many different places, how does one make sure it is all being accounted for and utilized appropriately?

In his book *Getting Things Done*, David Allen discusses the concept of "capture." He describes the importance of establishing a process for capturing *all* your inputs, having a designated location for storing them, and then establishing a process for figuring out exactly what to do with each input. This may seem extremely obvious, and perhaps it is, but it typically is not commonly practiced. Rarely does knowledge work allow for time to establish designated avenues for receiving inputs such that they are all funneled to a predetermined location. Even more rare is the practice of establishing a process for what to do with conflicting inputs. Typically, "figure it out as you go" is the standard operating procedure (again, Reactive Planning Model rearing its ugly head, because thinking is hard, and we as humans want to avoid it). (2015)

MSDGC, however, developed exactly this type of approach for resolving all the inputs to their models with their Model Archiving process.

MSDGC's Model Archive Process
MSDGC's vision includes a systematic approach for checking models in and out to project stakeholders, whether internal to MSDGC or external consultants. The model files issued for new project work is identified as an archived/vaulted model and each archived model requires a documented record of what is included in each of its versions. The model archive workflow is structured to provide consistent quality control for model updates and document the model updates with flexibility for different model project types.

MSDGC's starting point for administering a model archive workflow was to layout a file structure and naming convention that makes it clear to any user which model and model version they are using and the date it was archived. The naming convention addresses the basin name the scenario or planning horizon of the model, the date it was archived and the event it is setup to simulate. The model archive includes both the Typical Year and the 2-year 24-hour SCS Type II design events, to align with the regulatory requirements outlined in the Consent Decree for CSO and SSO compliance. The frequency of model archival varies based on the model basin. The combined sewer basins, where most of the consent decree work is being performed, are updated and archived quarterly. The remaining basins are updated annually, at a minimum.

The model archive workflow procedures had to address the Modeling Group's issues to date with model administration. Historically, model updates performed by MSDGC were completed as time allowed, and with many projects being performed concurrently, the number of required updates became overwhelming, leading to more potential for mistakes and omissions within the model. The workflow procedure had to not only document the model updates but provide quality control measures to ensure updates were consistent and correct. The model archive workflow addresses the following:

- What type of modeling projects to archive and when
- Model update methodology and quality control
- Model Archive results output and documentation
- Version control documentation

The different modeling project types were identified, and a separate workflow was created for each of the three types:

- Project Models: Model updates resulting from survey, construction, review of GIS data, modeling guidelines compliance and addressing known errors.
- Storm Volume Calibration (SVC) Models: Model updates resulting from MSDGC approved model calibrations performed in accordance with MSDGC Modeling Guidelines.
- Non-Vaulted Models: Modeling performed for alternatives analyses and conceptual planning that are not be archived and incorporated into the vaulted model.

Each model type workflow includes a review process by both MSDGC and as requested by MSDGC by an external reviewer.

Once the Project Models (PM) and Storm Volume Calibration Models (SVC) have been vetted and reviews are completed and approved, the project record is ready to be archived and incorporated into the vaulted model.

At the beginning of each quarter a meeting with the modeling group is held and each model basin is reviewed for completed and upcoming projects. A vaulting schedule is developed for the quarter based on known project completion dates and model basin priorities. The model vaulting process may take up to one month to complete depending on number of changes to incorporate and size of the model basin. The assigned vaulting schedule distributes the model basins across the three months of the quarter to spread the work evenly to minimize work overload and the potential for mistakes.

For a single model basin to be vaulted the model archive process each month begins with review of all the project records for the basin. The reviewed and approved project records include a pre model and a post model. The pre model is the model the project consultant received at the beginning of the project, the post model is the updated and modified model the consultant returns to MSDGC. Using a tool developed by Arcadis, the input files for both the pre and post model are compared, and a list of modifications is created to represent the library of changes made to the model because of the project. A library of changes is created for each project record and are reviewed concurrently to determine if there is any potential overlap, conflicting information, or items included that are not to be incorporated into the vaulted model. Occasionally, the post models will include data that was relevant during project completion, that will not be relevant in the vaulted model, including calibration time series files for observed rainfall or boundary conditions.

After review of each project's library of changes, the modifications are performed to the prior quarter's vaulted model, taking special care to review the modifications and ensure they comply with MSDGC modeling guidelines and do not overwrite prior valid updates or cause duplication within the vaulted model. Depending on the time of project completion, the pre model that the project consultant was provided may be rather dated and can affect the method in which the modifications are imported into the vaulted model. Once all the project records are incorporated into the vault, the draft vaulted model is run for a 2-month 24- hour SCS Type II design event and compared to the same model run from the prior quarter vault. The following items are reviewed:

- Warning Messages
- Instabilities
- Duplicate Infrastructure
- Disconnections or missing infrastructure
- Inactive input file data
- Conduit Peak Flow
- Manhole Peak Depth
- Manhole Flooding

If there are inconsistencies discovered or results that cannot be justified based on the scope of the incorporated projects, then additional investigation and resolution is required.

Summary of Output

Once the modeling projects are incorporated into the draft vaulted model, the model is simulated for the Typical Year event and the 2-year 24-hour SCS Type II design event. The results of these model simulations are summarized in tables that provide the annual combined sewer overflow (CSO) volume in the typical year and the sanitary sewer overflow (SSO) volume in a 2-year design event as well as node flooding. As another quality check these reported volumes are compared to the prior quarter's volumes. Differences in volume are highlighted and reviewed based on the scope of the projects incorporated to determine if they are justified. Again, if there are inconsistencies discovered or results that cannot be justified based on the scope of the incorporated projects, then additional investigation and resolution is required.

After any necessary investigations are resolved and the vaulted model for the quarter is finalized, additional model output is generated in the form of a GIS geodatabase. The existing conditions model for each basin is run for a series of design events including the 6-month, 2-year, 5-year, and 10-year 24-hour SCS Type II Design events and dry weather flow. The model results for all the link and node elements in every basin model are compiled and formatted into two shapefiles. The shapefiles report model results statistics for all the events simulated. For links, reporting includes peak velocities, peak flow rates, upstream and downstream manhole hydraulic gradeline and surcharge depths. For nodes, the reporting includes surcharge depth, freeboard, flooded volume, and flooded rate. This geodatabase is updated quarterly and access to the data is provided to all MSDGC staff. The model results are therefore accessible to any staff looking to understand capacity issues within the system, without having to know how to open and run a hydraulic model. Having this resource available reduces workload and interruptions for Modeling staff while reducing delays for other MSDGC staff.

Documentation

At months end, with all the project models incorporated into the new quarterly vaulted model, the vaulted model is officially documented in MSDGC Flowfinity application. The following documentation accompanies the vaulted model at completion:

- Individual Project Library of Changes
- Pre to Post Vaulted model Library of Changes

- Quality Control Notes Workbook
- CSO/SSO/Flooding Node Summary Tables
- GIS Geodatabase of Model Output
- Version Control Documentation

In the beginning, the version control documentation consisted of a word document listing all the projects contained within each basin model version. Projects and model updates that have not been incorporated are also listed for clarification of what is or is not included in a particular version of the model. Over time the version control developed into its own application within FlowFinity where each modeling project is listed as a record that moves through its own workflow once it is incorporated into the vaulted model. The records can be exported to a .csv table and reviewed.

The model archiving process and resulting Flowfinity workflow provides the MSDGC Modeling Group with documented and detailed records of all model updates performed. The output generated and uploaded to the vaulted model record provides easy access to model results for regulatory reporting and high-level planning. The model update process provides numerous points of quality review and consistency across all Modeling Group staff.

LESSONS LEARNED

General Guidance

- Develop a purpose statement with why you are developing this process, what you expect as outcomes, what you are not going to include, and what are your measures of success. This statement will inform new users what to expect, help you focus on what is most important, and put boundaries to prevent scope creep. Having a starting document also allows for comments and suggestions from other users which will improve your processes.
- Map out as much of the process as you can before starting the actual program development to reduce changes. After the initial mapping, update the process documentation as you go to reduce confusion later.
- Develop each new process in complete steps as much as possible. For example, the first process developed would be the method of transferring and documenting what was transferred to the calibration consultant – observed rain data, observed flow data, base uncalibrated model. The next step would be how the consultant transferred the model output back for review of calibration.
- Use an outside partner to test draft versions of your process to see where you made assumptions or skipped steps.
- In the case of software, problems may arise with limits on file size or types of files accepted by the program. Firewalls, anti-virus software, and corporate access regulations may also impact what type or size of files can be transferred. Research into access regulations may change how the process develops.

Confusion among users when processes change

- Changing processes will confuse users, especially those that are infrequent users.

- Update the documentation for the process at the same time as the changes are made. This documentation should be stored in an accessible location for all users with superseded documentation removed.
- Develop method of sending occasional summary messages to all users. For MSDGC's system, each user had a separate login rather than a generic corporate login. This individual account allowed for collection of direct email addresses for bulk emails of the changes.
- Flow charts are easier to understand than text explanations. Charts with descriptive text are best.

Excessive Demands

- When developing a new process, requests for additional information may become excessive. Compiling and packaging information costs time and budget. Refer to your purpose statement to focus on what is needed rather than what would be nice to have.

FINAL CONCLUSIONS AND ADVICE

One of the most impactful innovations made by Taiichi Ohno was the "Stop-Fix" approach. "In short, the Stop-Fix practice worked like this:

- A standard for quality was set
- All employees were trained on that standard
- If there was a deviation from that standard, any employee had the power to stop the entire assembly line by pulling a cord at their workstation. This was unheard of at the time.
- Management and employees then collaborated to solve the problem…
- The problem was fixed, and the assembly line would be restarted." (Allen 2015)

Recall from the Background section that MSDGC implemented all these changes during one of the largest calibration efforts in its history, and during its implementation, they effectively utilized the Stop-Fix approach.

What happened within MSDGC while utilizing the Stop-Fix approach is perfectly summarized/mirrored by what happened when Ohno first utilized this approach:

- "At first, the assembly "line stopped all the time".
- "Workers became discouraged".
- But over time, the "errors began to drop dramatically".
- While the line stopped more than a mass-production line at first, it ended up stopping way less.
- Today, this system has a significantly higher yield.
- "The amount of rework needed before shipment fell continually."
- "The quality of the shipped cars steadily improved."" (Allen 2015)

This exact scenario played out time and again while implementing these changes at MSDGC. In that it was extremely challenging and questioned by many in the beginning, but since the initial struggles, MSDGC's model review processes now result in much higher quality models, with minimal stoppage, significantly reduced time and effort, and is questioned very little by very few now that all metrics and documentation have been standardized, visualized, and centralized.

The overall point being made is this – streamlining your workflows is extremely difficult; requires time, patience, commitment, and conviction; and ultimately will be worth it when revolutionary gains are achieved.

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