APPLICATION OF DIGITAL ENGINEERING IN THE WATER SECTOR

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ABSTRACT

Auckland is expanding rapidly. Essential infrastructure needs to keep pace with this growth, including the water supply network. That's why Watercare utilised the Enterprise Model (EM) with its culture of collaboration and agile delivery to meet the challenge. The Waikato River to Redoubt (R2R) programme delivered an additional 50 million litres of treated water per day from Waikato River to Auckland. The R2R programme included 5 workfronts spread across Waikato A Phase 1 located in Tuakau and Booster Pump Station located in Papakura. The fast track nature of this programme, presented several challenges to design, consenting and construction teams. The programme needed to be procured, designed, consented, constructed and commissioned in parallel and within 12 months' time frame to meet Watercare's target operational date in line with predicted lake storage forecasts. Watercare, and its EM partners Beca, Fletcher Construction Company Ltd (FCC) and Fulton Hogan (FH) recognised the criticality of implementing effective digital engineering (DE) processes to achieve the outcomes of the programme.

DE enables the development of digital data that can be adopted during the life cycle of an asset. This paper is a case study of Waikato R2R and will study positive impacts of implementing DE approaches in this Programme. It describes how digital data created via a variety of authoring tools through collaboration on daily basis made 'the boat goes faster'. It also outlines development of digital data that commenced from design and progressed during construction and commissioning phases.

To implement a successful DE method, an automated process was developed to coordinate more than 80 design models and special files daily. A geospatial system created for the project, enabling flawless programmed daily collaboration across Beca and MTL who provided design support and between different models developed via a diverse range of tools, such as Revit, Plant3D, Civil3D, 12d, E3D, Navisworks and Recap Pro. DE helped the design and construction teams to coordinate continuously. This collaboration in the digital space enabled the construction team to provide rapid and efficient feedback on the practicality and constructability of the design information.

Verifying required design models was another initiative implemented for the Waikato R2R programme which significantly reduced the total number of required drawings. Coordinated and verified models provided digital data for FCC and FH, enabling digital construction rehearsal and construction. Construction teams empowered with information that was verified, digitally georeferenced and could be imported to machine controls. Machine controlled excavation enabled FCC and FH to accelerate the earthworks, construct efficiently, and reduce overall fuel consumption and environmental impacts of machinery.

To enable digital delivery of asset and as-built information, the DE team worked with Watercare to develop an asset data schema and as-built model specification. These guidelines assisted to upgrade design models to as built with respect to the construction programme and asset maintenance data. It also supported creation of digital asset information that is required for the operation phase. “Photograph 1” is an aerial image from Waikato site captured by drone.

Photograph 1: "Waikato Site Aerial Image"

KEYWORDS:

Smart Water, Digital Engineering, Virtual Collaboration, Digital Construction, Digital Operation Management

PRESENTERS PROFILE

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Matt Stanford has over 15 years' experience in designing and constructing complex multi-disciplinary water infrastructure projects where he has acquired hands-on experience in all phases of contract works.

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INTRODUCTION

Since the beginning of 2020, Auckland has received significantly less rainfall. In April 2020, the total volume of water stored in Auckland's dams dropped below 50 per cent. That is the reason why the Waikato River to Redoubt (R2R) programme initiated to deliver an additional 50 million litres of treated water per day to Auckland. Although a three to four years' timeframe would be required to deliver five new facilities, the Waikato R2R programme needed to be designed and constructed in parallel and within a year time frame. In order to successfully implement new DE processes, skilled practitioners with the knowledge and collaborative mindset were required to bring together disparate practices in a cohesive manner. Upon commencement of the project, the programme management selected a team from Watercare, FCC, FH and Beca to bring the strategic thinking to lead the DE programme. As a result of innovative approaches and strong programme focused implementation, the timeframe for the design and construction stages reduced significantly. Digital information enabled digital collaboration and digital construction, improving the overall project programme. Asset information required for facility management extracted from digital environments and the end users will have access to digital data during the life cycle of these five facilities. "Photograph 2" is a render from Boost Pump Station facility that highlights high level of collaboration took place in 3D space.

Photograph 2: "Render of Boost Pump Station Facility"

1. A NEW DIGITAL DELIVERY METHOD

At the start of the programme, a new digital delivery method developed to support digital delivery implementation across design, construction and operation phases. This method created based on four main steps and objectives that will be captured in this case study.

1.1. FIRST STEP: CREATING A UNIQUE GEOSPATIAL SYSTEM AND AUTOMATE DAILY DIGITAL COLLABORATION:

The innovation came through the process of sharing the verified and coordinated digital information in a collaborative and dynamic way. A unique geospatial system created for the programme enabled flawless programmed daily collaboration between different models developed via a diverse range of tools, such as Revit, Plant3D, Civil3D, 12d, E3D, Navisworks and Recap Pro. “Figure 1” highlights the programme overall workflow that supported creation of a single source of truth for coordination.

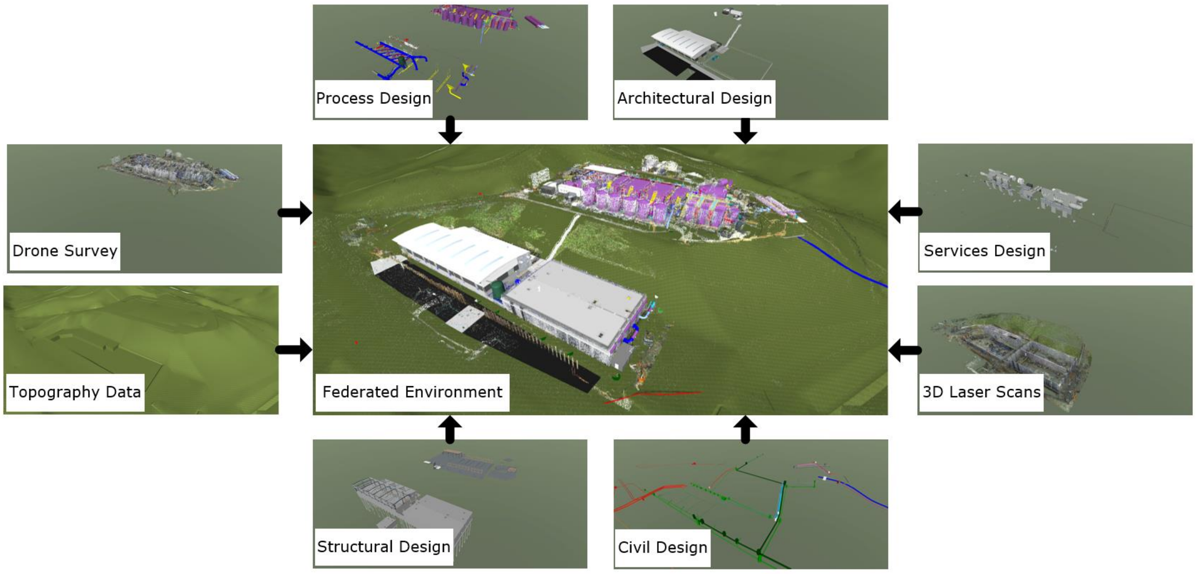
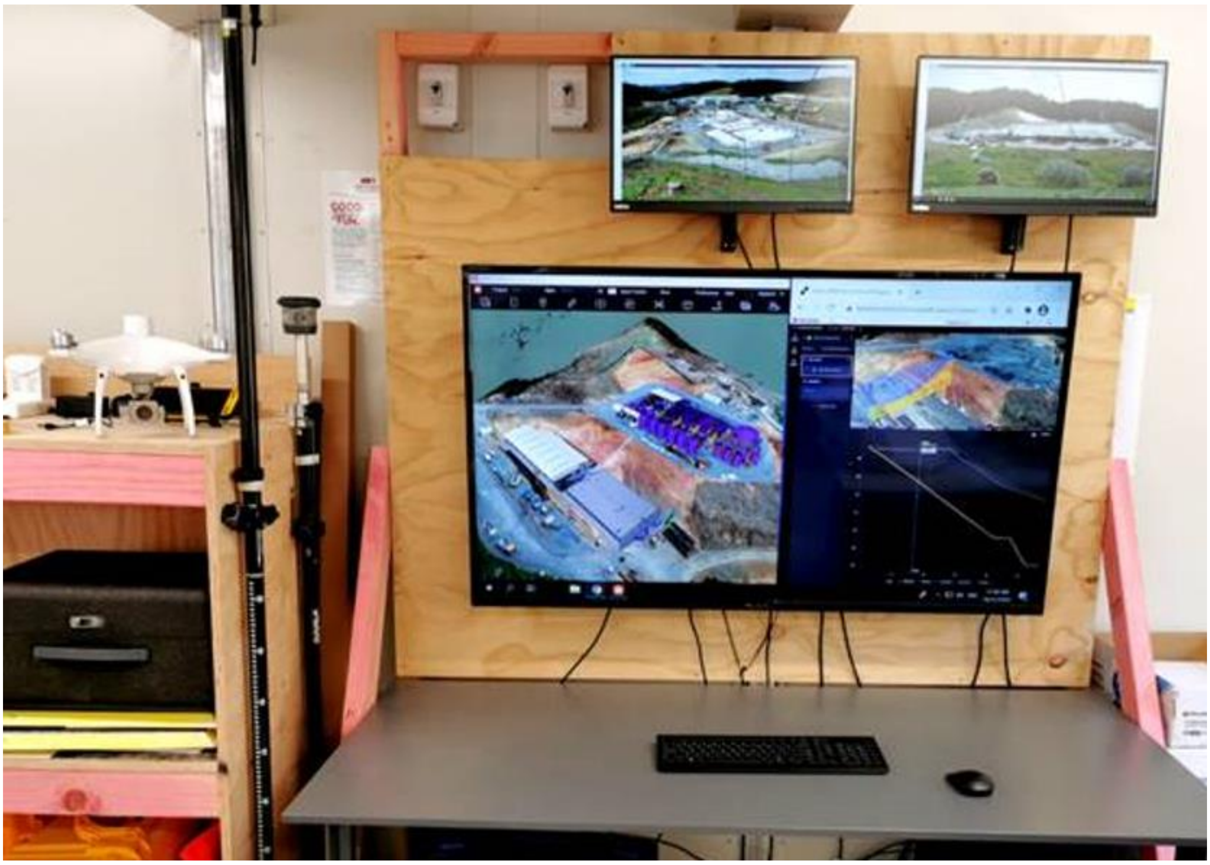


Figure 1: "The Programme Overall Workflow"

Design information which developed in more than 80 different models by different designers across Aotearoa and overseas, was automatically federated and shared with all users. This process programmed to operate automatically between 10pm and 6am every day during 12 months of design and construction works.

The new process helped the client, designers, and construction teams to coordinate seamlessly. This new collaboration method in the digital space enabled the construction team to provide rapid and efficient feedback on the practicality and constructability of the design information on a daily basis. Thanks to this new workflow, end users had open access to all digital asset information and monitor progress of design and construction. “Photograph 3” is snapshot of a station set up at construction site which utilised to share and coordinate design information with construction teams. Design models that shared via this platform updated on daily basis during construction stages.



Photograph 3: "Collaboration Station Set Up at Construction Site"

1.2. SECOND STEP: DIGITAL COLLABORATION TO IMPROVE CONSTRUCTION ACCURACY AND PRODUCTIVITY TO DELIVER PROGRAM OUTCOMES:

1.2.1. EARLY CONTRACTOR INVOLVEMENT (ECI) AND CONSTRUCTABILITY:

Through the digital collaboration tools, the construction teams empowered to provide rapid and efficient feedback on the practicality and constructability of the design being developed. This resulted in an efficient ECI design process which produced a robust buildable design, ultimately reducing the number of design iterations and issues experienced in the field during the construction phase.

1.2.2. CONSTRUCTING WITHOUT DRAWINGS:

DE helped the design and construction teams to coordinate work as design and construction progressed in parallel. Collaboration in the digital space allowed the construction team to plan and program works while the design was still being developed and drawings were unavailable.

Construction progressed without Issued For Construction (IFC) drawings being available and this enabled by sharing digital files extracted directly from the federated model. Ensuring the IFC status of the digital model elements was critical to ensuring the data being extracted from the model was ready for use. This information could be easily verified in the model space by adding design status metadata stamps to the model elements. Without the ability to construct in this manner, the construction program would not have been achieved. “Figure 2” highlights how design elements simply verified in consultant digital environment and verification status shared with construction teams through a simple colour coding system. Via this process, all Green 3D elements recognised as verified, Orange coordinated as work in progress and Red highlighted as on hold items.

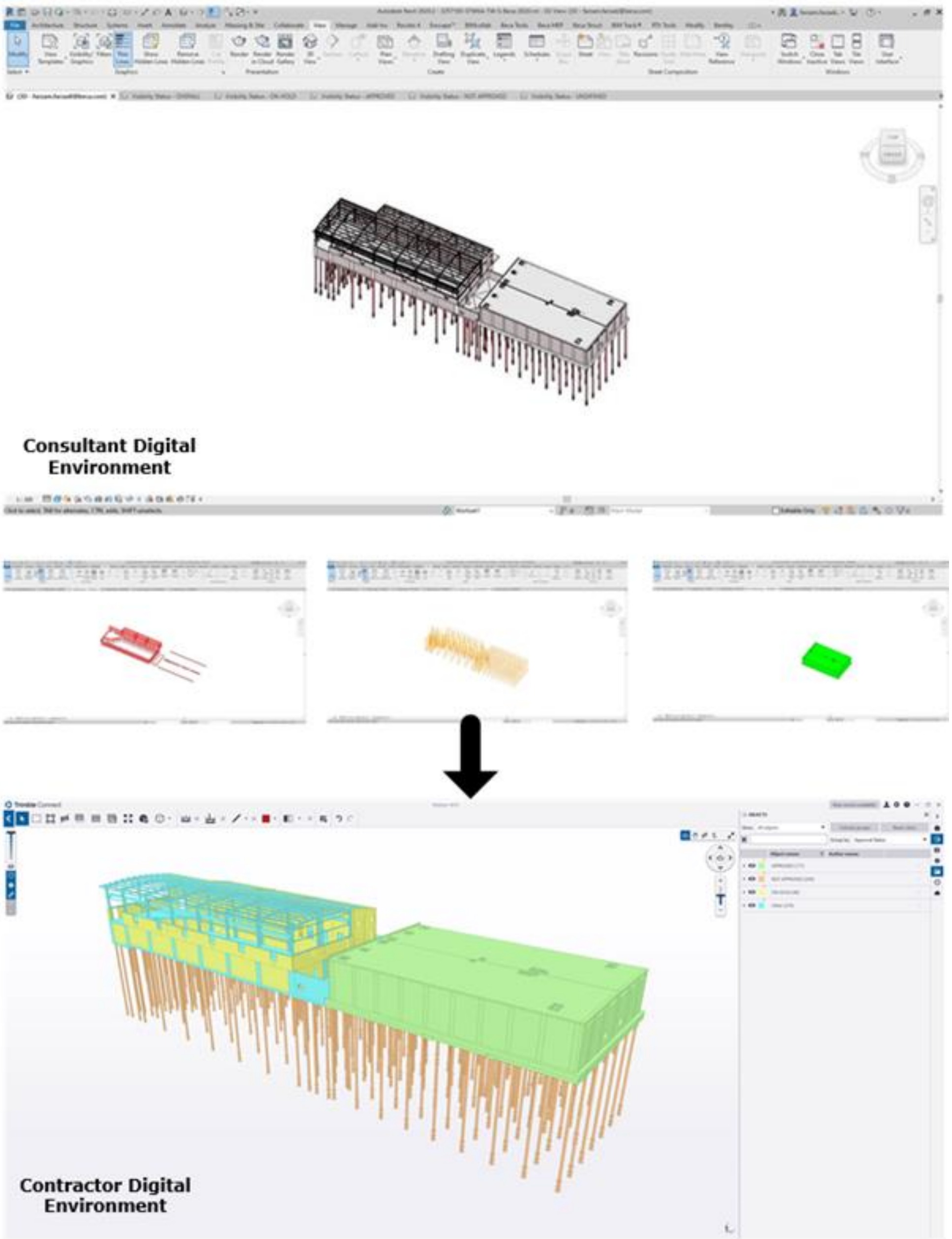


Figure 2: "The Programme Model verification Process"

1.2.3. INTEGRATING CONSTRUCTORS DESIGN WITH DESIGNERS FINAL DESIGN:

The constructor's temporary works design required for the construction of the asset can have a significant impact on how the permanent design should be developed. Through digital collaboration, the constructor and the designer could share temporary and permanent works to coordinate and verify a design solution that was effective and efficient. For the Waikato R2R programme, the temporary works design of the bulk earthworks surfaces drove the overall site layout and influenced the finished ground level design. The collaborative approach to this design minimised earthwork volumes and provided significant program gains.

1.2.4. IMPROVING PRODUCTIVITY AND ACCURACY THROUGH MACHINE CONTROL

Collaboratively developing a verified earthworks design made taking the step to machine-controlled excavation an easy choice. Machine controlled excavation enabled the constructor to accelerate the earthworks and reduce overall fuel consumption and environmental impacts of works. The exceptional accuracy and efficiency of the works resulted in significant program savings and provided the foundation's teams early access to a well-formed working platform. “Photograph 4” is a snapshot of machine controls utilised for the programme. “Figure 3” is a comparison of what designed in 3D environment against quality of final earthwork constructed on site.

Photograph 4: "Earthwork Via Machine Controls"

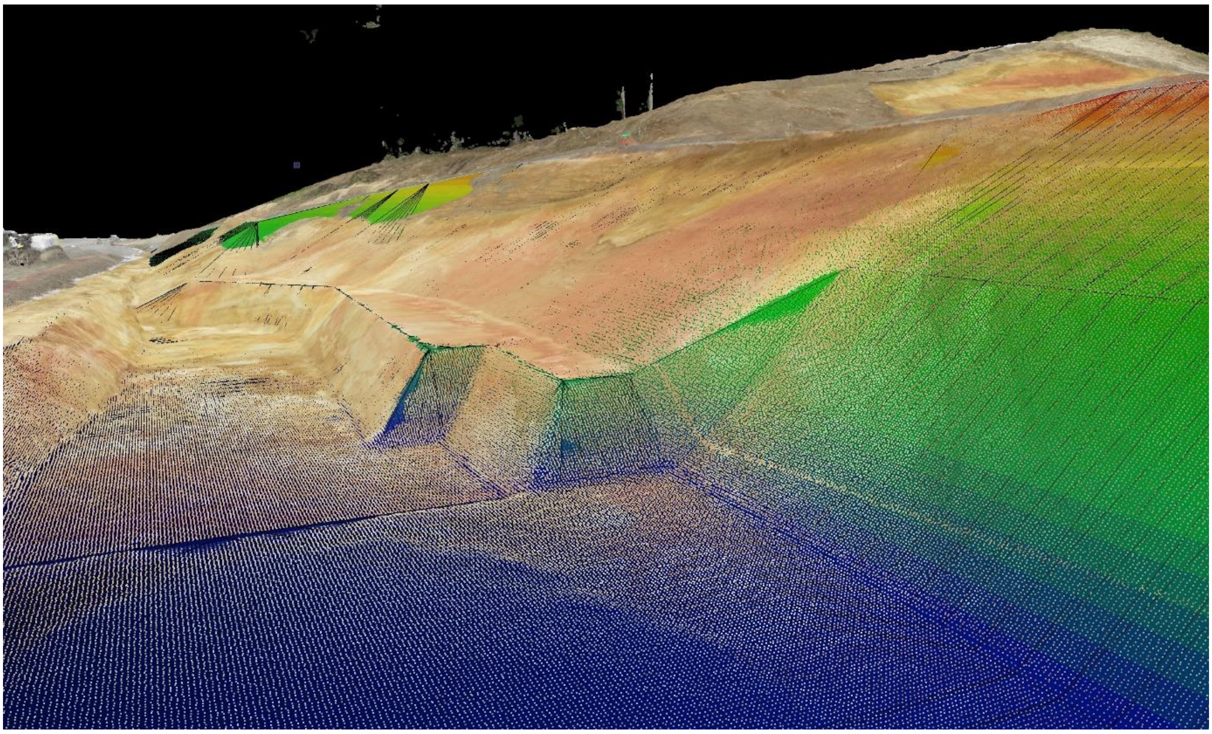


Figure 3: "The Accuracy of Machine Control"

1.3. THIRD STEP: INNOVATING A DIGITAL ECOSYSTEM TO CAPTURE AND POPULATE ASSET INFORMATION DIGITALLY FOR THE CLIENT

The requirements for defining assets can be differ depending on the objectives of the end user. To enable digital delivery of asset information with two different classification systems and support requirements of the Watercare operation management team, a unique system was developed that supported automatic data capturing from design models. It assisted populating digital asset information during the construction stage that is required for the operation and maintenance phases. As a result of the process, all captured metadata and asset information categorised and mapped onto digital asset management environment automatically. "Figure 4" is snapshot of an Asset Data Schema (ADS) developed for the programme to support asset management process.

Object Classification											
B	B	B	B	WC	B	B	WC	B	CON	CON	CON
BIM	BIM	BIM	BIM	BIM	BIM	BIM	TRAD	BIM	BIM	BIM	BIM
OmniClass Number	Level 1 Title	Level 2 Title	Level 3 Title	Acquisition value	Antenna base level above ground (IL)	Area	Assessed remaining life	Asset designed life	Bearing Type	Body Type	Calibration authority
23-11 17 13	Site Products	Retention Structures	Retaining Walls	x			x	x			
23-11 17 13	Site Products	Retention Structures		x			x	x			
23-11 21 13	Site Products	Pavements	Roadways	x			x	x			
23-11 21 21 11	Site Products	Pavements	Pavement Drainage	x			x	x			
23-11 21 21 15	Site Products	Pavements	Pavement Drainage	x			x	x			

Figure 4: "The Programme Digital Asset Management Process"

1.4. FORTH STEP: IMPROVING SUSTAINABILITY THROUGH MAXIMISING TRANSPARENCY

Digital processes improved transparency of the design process. Design members, construction and maintenance teams had access to graphical and non-graphical data that updated daily. This capability enables all parties to receive information on what equipment, products and materials proposed by design teams, how they would be constructed or fabricated off site, and what will be energy consumption of these facilities.

The high level of transparency enabled contractors, engineers and venders to provide feedback on sustainability aspects of design information. This approach resulted on selection of materials and equipment that were environmentally friendly and meet the programme sustainability objectives. Team members also had the opportunity to review, study, simulate and enhance the design content at every step. Minimising the programme time frame, improving efficiency, enhancing design information, reducing reworks on site, and providing data that can be utilised during the lifetime of assets had significant impacts to meet sustainability objectives of the Waikato R2R programme.

Developed digital data during the design phase and captured information during the construction stage created a high level of control at through commissioning and during asset operations and maintenance. At the early stages of project development, a specific asset data schema was developed for all facilities. The schema identified all assets and highlighted the data that was required for operation and maintenance of these assets. It also covered what data needed to be captured for Operations, and which party was responsible to provide the required information. At the end of commissioning and handover phase, all digital information was shared with the client via a digital twin platform which had direct impact on sustainability. “Figure 5” is snapshot of studies took in place in digital environment to maximise quality of design and minimise energy consumption of the programme.

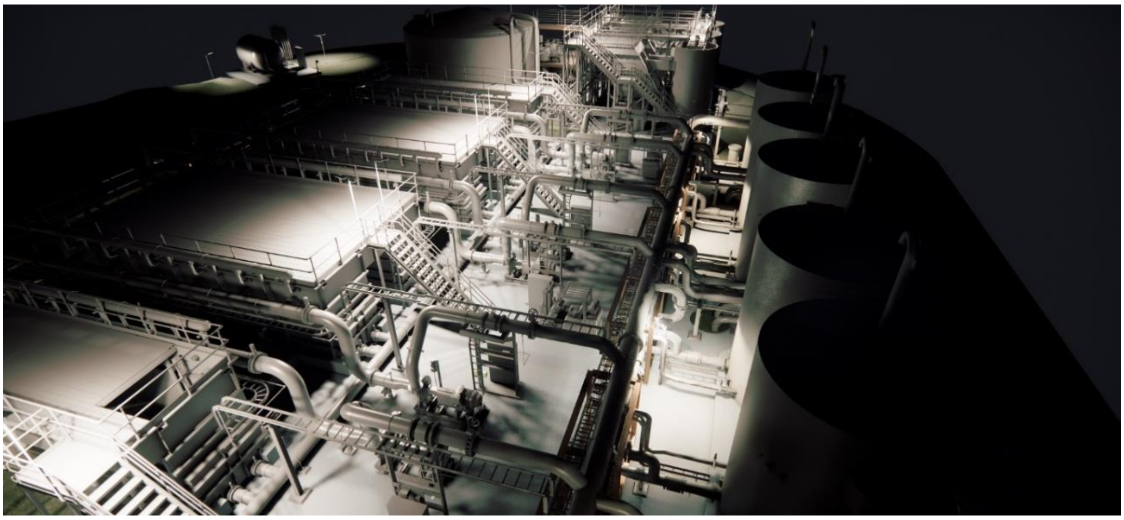


Figure 5: "Energy Consumption Studies in the Digital Platform"

2. PRIMARY CHALLENGES

2.1. CULTURAL CHANGE

Cultural change is a crucial factor to successfully implement new processes in the construction industry. The project team developed a new digital delivery method that improved digital collaboration and agile delivery across design, consenting, construction, commissioning and operation phases. Although resolving technological issues were challenging, cultural change can be identified as the most vital challenge that the team faced during the programme. To be able to implement new digital approaches, the team needed to change the focus of the project members from endless drawings to 3D digital information. Traditionally core delivery teams focused on producing 2D drawings, redline mark ups and coordinated 3D digital information were secondary. To change this mindset the programme team ran more than 30 workshops and trainings in the last 12 months to communicate digital delivery processes and requirements to enhance understanding and acceptance. Arguably the culture of EM had significant impact on the high level of collaboration and agile work practices that took place between all stakeholders in the digital environment which was fundamentally built on the trust that developed within the team.

2.2. TECHNOLOGICAL ISSUES

There were over 80 3D models produced by a team of more than 70 designers that needed to be automatically collaborated and federated every day. A unique geospatial system needed to be created to support interoperability challenges between more than seven design authoring tools and coordination platforms. Some of the design information needed to be verified in digital format to enable digital construction. All design models required to be upgraded to as built level for the operation phase. All design and construction data needed to be classified automatically to support Watercare facility management requirements and ambitions. All above objectives created variety of technological challenges for the programme team members that resolved through high level of collaboration among Watercare, Beca, FCC and FH.

3. AN EXAMPLE OF DIGITAL COLLABORATION IN PRACTICE – WAIKATO 50 (W50) TIE-IN WORKS

3.1. THE PROBLEM

A connection from the new W50 plant to the existing Waikato 1 (W1) pipeline was required in order to deliver the additional capacity produced by W50 to Auckland. The existing W1 pipeline is a piece of critical infrastructure that at the time was delivering approximately 40% of Auckland’s water. This critical tie-in needed to be undertaken safely, and accurately within a specific shut-down period of 24hours, not only this but at Dn1200 and with an operating pressure of approximately 15bar the tie-in was one of the largest ever completed on a WSL asset.

There was uncertainty around the actual alignment and depth of the as-built asset, initial investigations indicated that the pipe had both horizontal and vertical changes in alignment at the point of connection. This meant making the cut and installing the new 16t tie-in assembly could be difficult as there were concerns that deflections at the weld band connection points could be exceeded and additional filings may have been required, adding time to the installation duration.

3.2. THE DIGITAL APPROACH

Temporary works design of the excavation in 3d space to verify clearances and maximum span of the exposed pipeline, also used to verify the temporary shoring system, where sheet piles needed to be removed, and confirm lift plans. Lazer scanning of the exposed asset produced a 3D point cloud if the as-built asset.

An as-built model was developed from the point cloud and incorporated into the federated model. This allowed the constructors and designers to determine the optimum positioning of the tie-in assembly, ensuring alignment to the W50 pump station and that deflection limits were not exceeded. Effectively the team undertook a digital rehearsal of the cut-in process to validate the planned works.

The verified positioning of the tie-in assembly was loaded into the federated model and shared with the construction team who then extracted the position and accurately marked out the cut locations on the asset using site survey equipment. The tie-in assembly methodology was refined to suit the verified cut locations and known deflections. "Figure 6" is a snapshot of coordination that took place in digital environment resulted in successful execution of tie-in works.

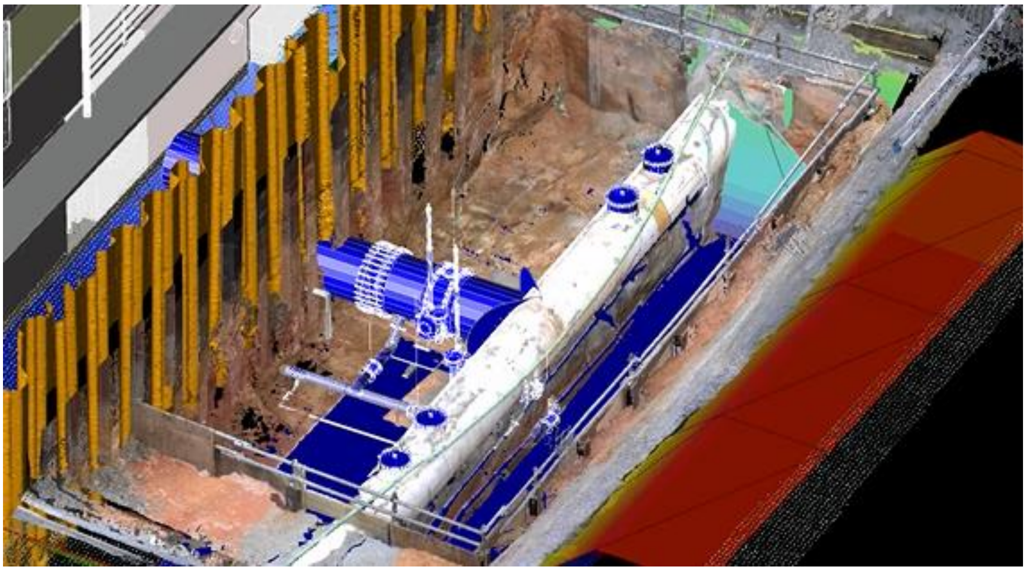


Figure 6: "Tie-in Digital Rehearsal"

3.3. THE RESULT

The tie-in works were executed in just 10hrs with the excellent alignment of the pipework for connection to W50 pump station discharge. This work package recognised as high-risk exercise to the programme at commencement stage. Through implementing DE methods, this risk fully managed and execution phase completed flawlessly.

CONCLUSION

More than 1000 people worked directly or indirectly on the Waikato R2R programme as a team to achieve the required outcome of the project. To be able to reduce three to four years' worth of effort to a 12 months' time frame, the team needed to collaborate and operate differently. There were over 80 design models produced by a team of more than 70 designers that needed to be automatically collaborated every day to minimise the design phase of 5 facilities to a 4 months' programme. A unique geospatial system needed to be created to support interoperability challenges between more than seven design authoring tools platforms. Some of the design information needed to be verified in digital format to enable digital construction. All design models were required to be upgraded to as built level for the operation phase. All design and construction data needed to be classified at both asset and element levels automatically to support the Watercare facility management requirements. The Digital method implemented for the programme supported the project stakeholders to collaborate efficiently regardless of their locations or time zones.

REFERENCES

Cherrington, M., Lu, Z., Xu, Q., Thabtah, F., Airehrour, D. and Madanian, S. (2020) 'Digital Asset Management: New Opportunities from High Dimensional Data—A New Zealand Perspective'

Hwang, B., Ngo, J. and Wan Yi Her, P. (2020) 'Integrated Digital Delivery: Implementation status and project performance in the Singapore construction industry'

Meinert, E., Milne-Ives, M., Surodina, S. and Lam, C. (2020) 'Agile Requirements Engineering and Software Planning for a Digital Health Platform to Engage the Effects of Isolation Caused by Social Distancing'

Novikov, S.V. and Sazonov A. A. (2020) 'Digital transformation of machine-building complex enterprises'

Kong, T., Hu, T., Zhou, T. and Ye, Y. (2020) 'Data Construction Method for the Applications of Workshop Digital Twin System'