# CHRISTCHURCH FLUORIDATION: IMPLEMENTATION PLANNING FOR A 40+ FACILITY SYSTEM

***Jack Deeley (Jacobs), Michele McDonald (Christchurch City Council), Silvia Vlad (Jacobs)***

**ABSTRACT**

Following the promulgation of the Health (Fluoridation of Drinking Water) Amendment Act in 2021, water suppliers were encouraged to proactively commence fluoridation-related preparatory work on community supplies which service more than 500 people. Christchurch City Council provides drinking water to over 390,000 residents and is also responsible for the provision of safe drinking water to various small communities spread across Banks Peninsula. Because CCC does not treat water at most of its facilities beyond the addition of chlorine, the overall water supply system configuration is different from many large municipalities. This presents unique challenges when considering the fluoridation of drinking water.

CCC have undertaken the development of a comprehensive concept plan for the implementation of fluoridation at CCC public drinking water supplies, which encompass more than 40 pumping stations across the City and Banks Peninsula. Key factors and considerations established in the concept plan include the selection of fluoridation chemical and dosing method, integration with existing infrastructure including process equipment and controls, accessibility for operation and maintenance activities, operator health and safety and the standardisation of fluoridation equipment across the district. The key driver for this project was to get a clear and reliable understanding of the implications for CCC, specifically the capital investment required as well as operation and maintenance costs of implementing fluoridation.

Building on a preliminary system-wide implementation plan, conceptual designs were developed for five representative reference sites. The selected sites span a range of pumping capacities (1-11 ML/day), pumping configurations (artesian wells, well supplies with and without suction tanks, wells pumped to storage or directly into mains) and water quality characteristics (both ground and surface water supplies). Conceptual designs for two different chemical types were developed for a mid-sized facility, to consider the differentiators between application of two common fluoridation chemicals: sodium fluoride (solid) and hydrofluoric acid (liquid).

The five reference concepts have been used as the basis for the development of a staged implementation plan the over 40 facilities operated and maintained by CCC. This incorporates considerations for population served and potential benefits to the community, coordination with other capital projects and potential cross-over implications for ongoing chlorination optimization efforts. It also informs the CCC long term plan.

Using the CCC case study, this paper provides a review of considerations, potential pitfalls and key lessons learned for fluoride implementation, spanning chemical selection, layout development, controls integration and design standardisation. It presents a recommended approach for the implementation of fluoridation, highlighting the unique considerations needed for implementation at the scale of 45 facilities.

**KEYWORDS**

**Fluoride, standardization, implementation planning, chemical systems**

**PRESENTER PROFILE**

Jack is a process engineer at Jacobs with a passion for drinking water treatment in the water infrastructure sector. He has particular interest in chemical dosing systems and the evolving drinking water treatment methods in New Zealand. His qualifications include BE (Hons) Chemical and Process.

Michele is a professional civil engineer and chartered member of Engineering New Zealand. Her career over the past 30 years has focused on strategic planning, information engineering and programme management in the water and wastewater sector. She is currently fulfilling the role of Team Leader, Asset Planning - Water and Wastewater for the Christchurch City Council.

# INTRODUCTION

The NZ Health (Fluoridation of Drinking Water) Amendment Act 2021 (the 'Act') came into force on 13 December 2021 and mandates the Director-General of Health to direct a local authority to add or not to add fluoride to drinking water supplies servicing more than 500 people. The Act requires the Director-General to consider the cost and expected timeframe for implementing drinking water fluoridation before issuing a directive. Immediately after the promulgation of the Act, the Director-General of Health requested that New Zealand local authorities confirm the status of fluoridation of their drinking water supplies and where drinking water supplies were not fluoridated, to provide the anticipated costs and timeframes required to implement fluoridation. Whilst local authorities were encouraged to start fluoridation-related preparatory work, it was also highlighted that there would be no need to wait for a direction from the Director-General before implementing the addition of fluoride to drinking water supplies. It was indicated that some funding would be made available to support the implementation of fluoridation. Local authorities were required to respond to the request for inputs by 11 March 2022.

The Christchurch urban drinking water supply system serves a population of approximately 390,000 and is unique for a city this size, because it does not contain any water treatment facilities. Water is pumped directly from the deep confined aquifers below the city, detailed in Figure 1, at multiple, dispersed locations into a localized reticulation network.

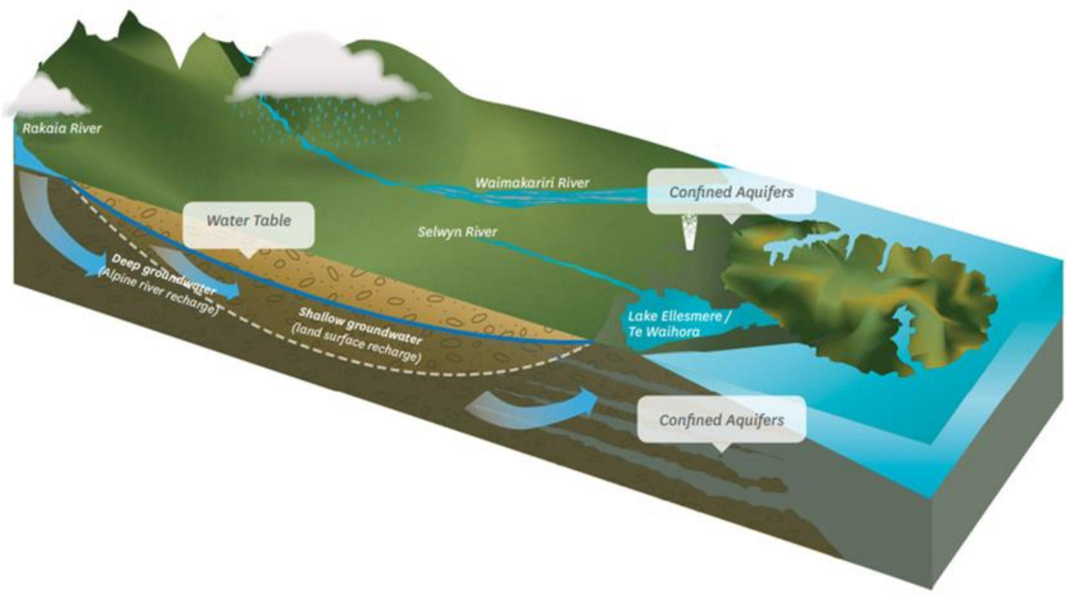


*Figure 1: Schematic of aquifers prevalent in the Canterbury Plains*

Only parts of the city which border the hills to the south are supported by water storage facilities. The largest trunk main, sized at 600 millimetres in diameter, connects the central city to the Huntsbury 1 reservoirs. A high-level overview of Christchurch urban water supply network is shown in Figure 2.

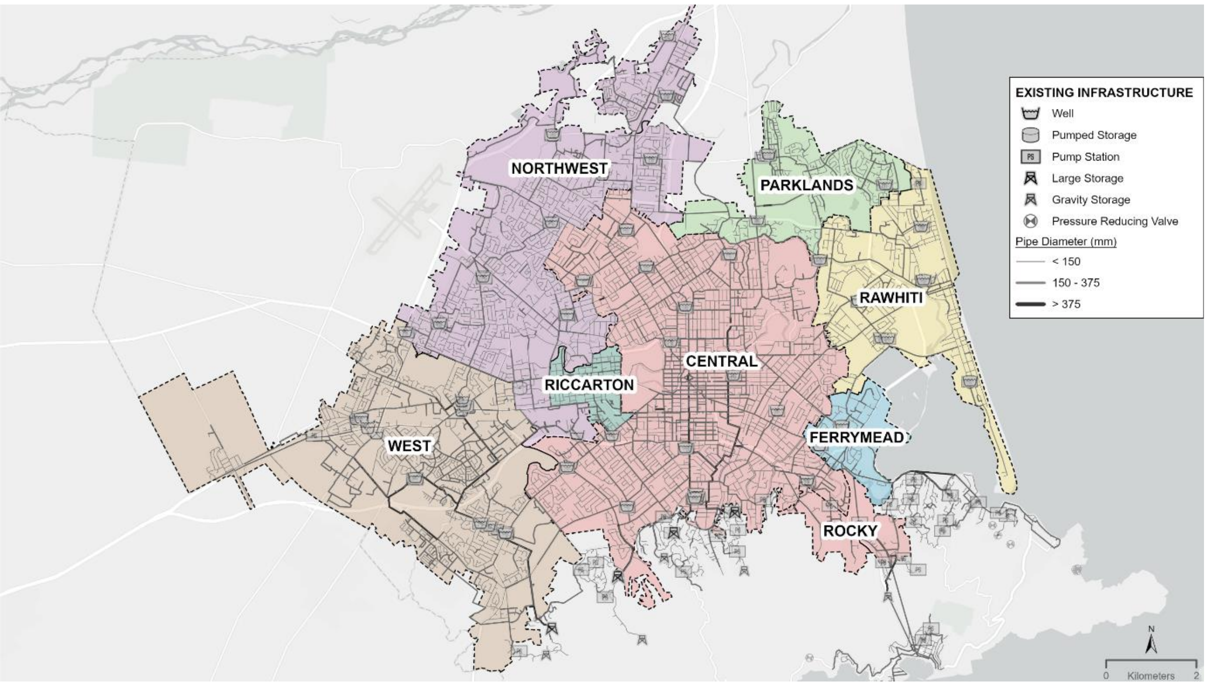


*Figure 2: Christchurch Decentralized Urban Water Supply System*

A total of 49 pump stations currently supply drinking water to the 7 primary water supply zones and these facilities vary in both size and configuration. The smallest pump station delivers up to 30 Litres per second of water (108 $m^3$/hr) while the largest pump station can provide up to 370 Litres per second of water into the network (1,320 $m^3$/hr). The configuration of the pump stations can be broadly grouped as follows:

1. submersible well pumps, pumping directly into the network (13)
2. surface pumps connected to artesian wells, pumping direct into the network (10)
3. combination of the above (2)
4. artesian wells or submersible pumps supplying into suction tanks with surface pumps, pumping into the network (24)

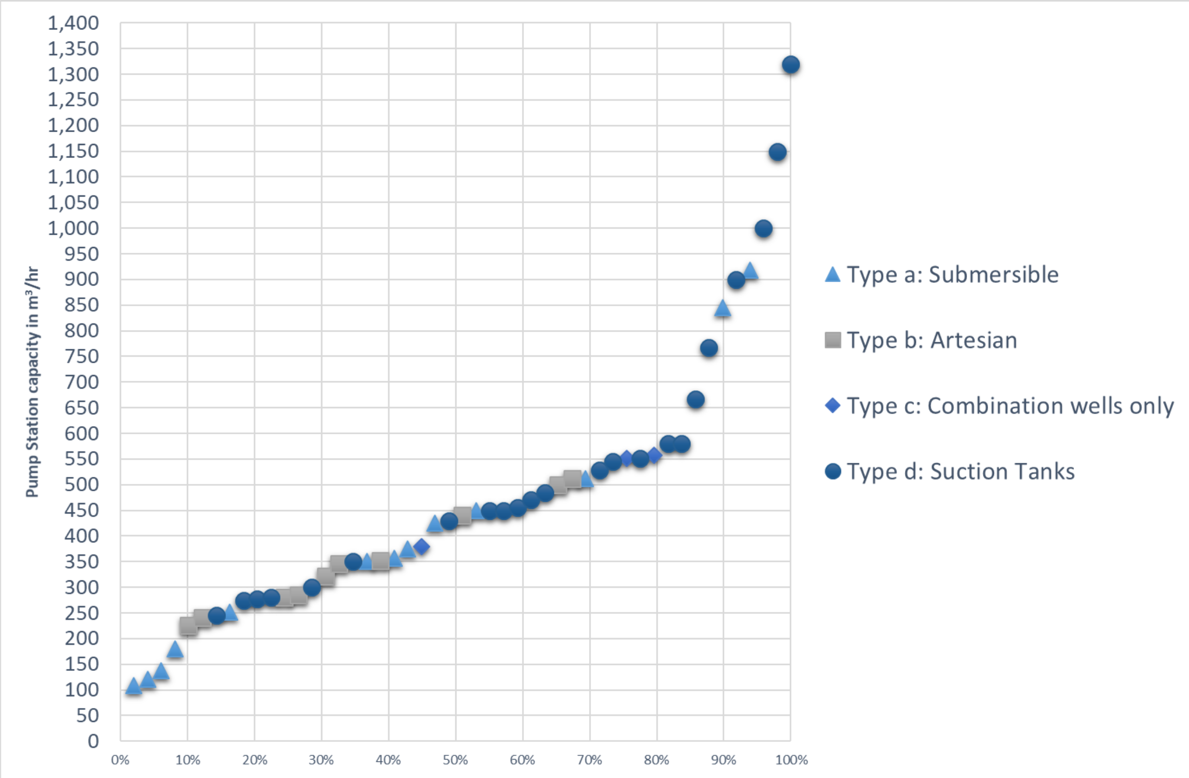


*Figure 3: Distribution of Christchurch water supply pump stations*

The Christchurch rural water supply systems are sourced from both shallow groundwater and surface water and include varying degrees of water treatment. Only the Akaroa water supply treatment plant services a population of more than 500 people and will therefore be subject to fluoridation requirements per the terms of the Act.

At the time when the Health (Fluoridation of Drinking Water) Amendment Bill was first introduced, Christchurch City Council obtained a baseline cost estimate from its service provider (*Costing of the Fluoridation of Christchurch Water Supply, City Care Ltd, Apex Environmental Ltd, Bremca Automation Ltd, 29 April 2017*). The baseline cost estimate determined that the implementation of fluoridation at 59 facilities (of which 49 are currently supplying the network), would require an investment of $20.1 million and an ongoing operation and maintenance cost of $0.91 million per annum (in 2017 dollars).

Since the removal of the provisional secure groundwater status in December 2017 and the subsequent decision to introduce temporary chlorination in March 2018, Council have gained further insight into the complexities involved in introducing treatment chemicals into the Christchurch decentralized water supply system. When the Christchurch City Council was requested on 15 December 2021 to provide information to the Director-General concerning the costs and complexities to add fluoride to its drinking water, it was therefore considered critical that the concept designs and the baseline cost estimate should be revisited. Matters which were not adequately considered in the initial baseline cost estimate relate to:

- Severe site constraints
- Proximity to the public
- Proximity of pumped supply to customer connection points
- High flow variability of individual pump stations
- Lack of permanent structures to house equipment
- No water quality monitoring control points
- Command and control systems not equipped for treatment controls

In mid-January 2022, the Christchurch City Council approached Jacobs to develop a revised concept plan and costing that would more accurately advise the implications of drinking water fluoridation. Jacobs were tasked to provide the necessary input to enable the Christchurch City Council to respond to the Director-General's deadline of 11 March 2022. The objectives of the work package were to:

- Review and formalize the fluoridation design concept
- Consider potential implications of an integrated chlorination and fluoridation solution
- Develop concept layouts aligned with pump station size and site constraints at selected facilities
- Provide a capital cost estimate for each future dosing site
- Develop a zero-based operations and maintenance budget for fluoridation including consideration of ancillary management and staff requirements
- Produce an implementation programme which recognizes operational constraints related to summer water demand and the roll out of water safety implementation actions

The Christchurch City Council established a dedicated working group to support the project team in meeting the tight delivery timeframes.

# DISCUSSION

## IMPLEMENTATION PLANNING APPROACH

A phased implementation planning study was undertaken to consider the fluoridation approach across 45 water treatment and pumping facilities spanning the Christchurch/Lyttleton, Brooklands-Kainga and Akaroa systems.

## PHASE 1 – CONCEPT REVIEW AND ESTIMATE UPDATE

Phase 1 focused on a concept review, confirming key project fundamentals, identifying the extent of integration with the Christchurch City Council's Chlorination Readiness project, and updating previous estimates for implementation costs. Conceptual estimates for capital, operating and maintenance, and renewal costs were developed based on assumptions previously established by Council, alongside a preliminary implementation schedule.

### HFA CONCEPTUAL DESIGN BASIS

Hexafluorosilicic acid (HFA) was noted to be the preferred chemical for fluoride dosing based on discussions held prior to establishing the baseline cost estimate in 2017. A liquid chemical system was therefore assumed for the system design basis. As a hazardous substance with corrosive classifications, the use of HFA has implications for personal protective equipment (PPE) requirements, building design and material selection.

Key considerations for the design of the HFA fluoridation system included:

- Developing a standardized, repeatable design which could reduce the variability and customization required for individual facilities
- Allowing for chemical delivery by a three-axle delivery vehicle, ideally without the need to reverse into or out of the delivery area.
- Selecting appropriate tie-in points for chemical dosing and fluoridation sampling, with consideration given to any potential interactions with other chemical equipment, flow meters
- Providing sufficient mixing between fluoride dosing and analyser sampling points, via the use of carrier water dilution, and where necessary, in line mixers
- Housing the fluoridation equipment in a durable structure to protect Council's investment in the new assets and reduce the potential for vandalism
- Minimizing the need for operators to enter to hazardous chemical areas by segregating electrical and controls equipment from the chemical room
- Integrating provisions for safe handling of HFA, including eyewash stations, HFA scrubbers and vapour detection systems

- Providing forced ventilation and external tank venting, as well as selecting appropriate materials to minimize the corrosive impact of HFA fumes in the chemical room
- Allowing for appropriate clear distances around equipment in the chemical room and a roll-up door for access, to support efficient maintenance activities
- Providing adequate controls to mitigate the risk of overdosing above the maximum allowable value (MAV) of 1.5 mg/L, by using a day tank, filled once per day, and equipped with online measuring device, in combination with a fluoride concentration analyser downstream of the dosing location

A simplified process block diagram of the HFA system design is presented in Figure 4. Chemical delivery via 200 L drums was assumed, with the fluoridation equipment to be housed in a new slab-on-grade building with two separate spaces: a chemical room, and an electrical and controls system room.

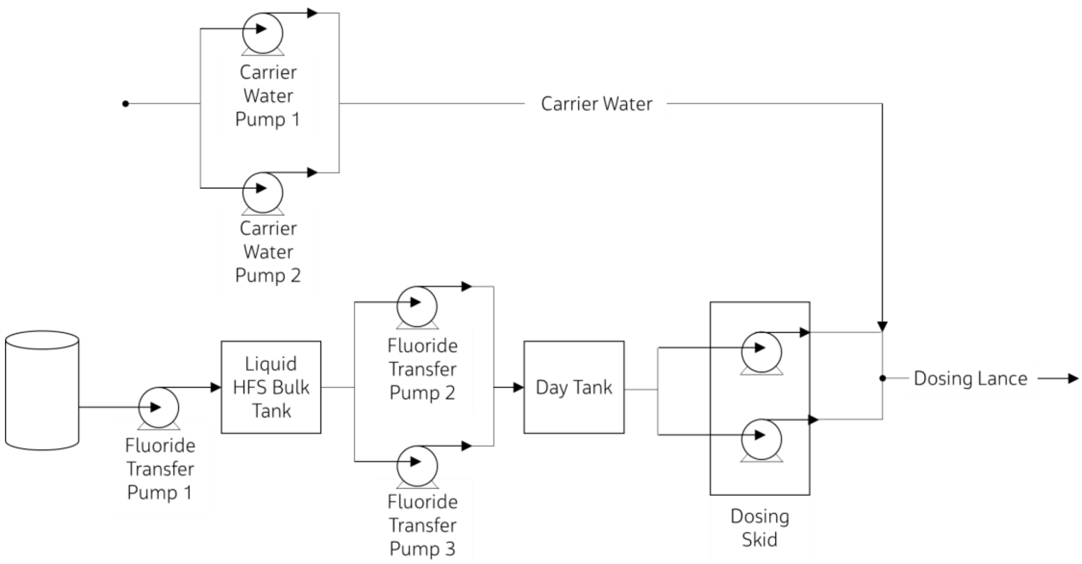


*Figure 4: HFA system block diagram*

A target dose of 0.9 mg/L was used as a conservative dosing concentration. Prospective fluoride injection points were reviewed and it was established that for most facilities, the dosing tie-in would be in a metering chamber downstream of the pumps, with a sampling point upstream of the first diversion from the pump discharge main to the reticulation system. Adequate mixing between the chemical injection point and the analyser sampling location is critical to obtaining an accurate measurement of fluoride concentration, and therefore where less than 30 pipe diameters were available between the dosing location and the sampling location, allowances were made for an inline mixer to provide adequate chemical dispersion.

**PRELIMINARY COST ESTIMATE**

The conceptual cost estimating approach was based on the categorisation of pump stations into three categories by flow rate, to allow the design team to leverage the conceptual level of design and meet the Council's time constraints. Updated budgetary pricing was obtained from equipment and chemical suppliers, and allowances based on similar reference projects were used to supplement the budgetary quotes.

The 45 sites included in this implementation study were categorised based on maximum flowrate as shown in Table 1. Not all sites were considered due to various reasons including pump station decommissioning or renewals.

*Table 1: Facility size categorisation*

| System Size<br>Maximum flow (m3/hr) | Small<br>300 | Medium<br>600 | Large<br>1320 |
|---|---|---|---|
| Christchurch/Lyttelton | 8 | 26 | 8 |
| Brooklands/Kainga | 2 | | |
| Akaroa | 1 | | |

A baseline implementation cost estimate was developed for the process equipment, building services, electrical, instrumentation, controls, structural and civil requirements.

The baseline costs were estimated for upgrades which were required on all sites such electrical wiring and connections, extraction fans, building and site security etc. A review of site layouts for all 45 facilities was undertaken, and it was noted that while some sites have ample space for new building footprints and chemical delivery truck access, others are constrained with numerous buildings and trees on site, increasing the complexity of civil construction efforts. Similarly, some facilities already have wastewater sewer connections for waste tank discharge, while the scope of fluoride implementation for other sites would require either establishing a sewer connection, or provision for waste removal by tanker truck.

Based on the site layouts review, sites where additional civil efforts would be required were identified, with markups tailed to reflect:

- the need for tree removal
- the range of site constraints (none, minor, medium, high)
- the range of delivery constraints (none, minor, medium)
- the proximity of a wastewater sewer connection (connection already available on site, connection available near the site at the adjacent road, connection removed from the site at a significant setback, or no wastewater connection available in the area of the facility)

Global construction markups were included based on the anticipated complexity of the construction phase, covering contractor preliminary and general cost, mobilization and demobilization, overhead, profit, risk and warranty requirements.

Non-construction costs for Council were also estimated, to capture internal costs associated with the implementation of fluoridation. This includes global upgrades/modifications to SCADA/programming, documentation updates to asset management systems, as-built drawings, operation and maintenance manuals, additional chemical/safety labelling to sites, staff training and permitting / consenting. These additional costs totalled 35% of the total outrun costs.

A 30% contingency appropriate to the level of design development was included, and 5% annual escalation was also incorporated based on a review of the Heavy and Civil Engineering Construction Index from 2019 to 2021 (Stats NZ, 2021). The total programmatic implementation cost was estimated at $58,050,000 (+/-30%) across all 45 facilities, including contingency.

The operational cost estimate considered chemical costs, as well as compliance, operating and maintenance effort for Council staff, based on a 16-activity breakdown which included grab sampling, annual testing, instrument calibration and callout responses.  These activities were estimated to total approximately 3.5-full time equivalent staff per year.

The chemical consumption estimates were developed based on the total flows in the previous fiscal year. This included the estimated cost for disposal of the chemical containers as hazardous waste, as well as contract management for the supply contract.

Anticipated costs to maintain the new equipment in a state of good repair were estimated based on typical midlife intervention frequencies and anticipated useful lifespans for different asset categories.

The renewals estimate determined the anticipated costs to maintain the new equipment in a state of good repair and were estimated based on typical midlife intervention frequencies and anticipated useful lifespans for different asset categories. Liquid chemical systems were assumed a lifespan of 10 years along with all appurtenances (e.g., piping, tanks) along with health and safety equipment while electrical and structural assets had a longer useful life of 30-40 years. A 20-year horizon estimate provided a breakdown of expenditure into a timeline to determine when larger reinvestments were to arise.

A conceptual implementation schedule was developed based on a six-month planning period followed by design, tendering, construction, and commissioning of 15 facilities in each of three assignments (primary, secondary and tertiary), for a total of 45 facilities commissioned approximately 3 years after the start of implementation. As system capacity requirements are highest in the summer months, activities which include facility downtime (equipment installation, start-up and commissioning) have been scheduled in the period from April to November. This scheduling is predicated on significant design standardization to allow for fast-tracked design of the secondary and tertiary facilities. A six-month equipment lead time is included assuming traditional procurement practices and drives the critical path. Pre-purchasing of key equipment may present an opportunity to expedite the schedule, particularly in the case of the primary facilities. This developed an estimated schedule spanning approximately 4-5 years.

## PHASE 2 – REFERENCE CONCEPT DEVELOPMENT

The Phase 2 of implementation planning focused on progressing the design for selected reference facilities, and reviewing some of the key assumptions made in Phase 1, including:

- Developing site-specific HFA-based fluoridation concept designs at five reference facilities
- Developing a site-specific concept design based on the use of sodium fluoride (NaF) as the fluoridation chemical at one of the five reference facility, for comparison purposes
- Updating capital and operating cost estimates for the refined reference designs

*Table 2: Chemical selection considerations*

| Factor | HFA | NaF |
|---|---|---|
| Product form | • Liquid<br>• 21% to 40% $H_2SiF_6$<br>• 23% reference concentration with 79% available F content | • Power or crystal<br>• ≥ 97% NaF; 98.2% NaF typical |
| Delivery | • 200 L drums<br>• Chemical transferred from drums to bulk tank via transfer pumps | • 5 kg canisters or 25 kg bulk bags<br>• Alternate solids handling systems |
| Health and safety | • Corrosive<br>• Typical PPE: full-face shield and/or splash-proof googles, long sleeved gauntlet neoprene/rubber gloves with sleeves folded back, heavy-duty acid type neoprene apron, chemical resistant boots | • Toxic<br>• Typical PPE: Long-sleeved overalls, leather gloves, goggles, dust mask |
| Design and construction considerations | • Requires pipe-in-pipe configuration, ideally PE pipes for dosing, venting of all areas with potential vapour accumulation, PVC/epoxy-lined tanks and containment | • Fewer design constraints regarding co-location of other equipment<br>• Larger footprint required for dry chemical handling, particularly at large facilities |

| | | |
|---|---|---|
| | • Potentially higher overall equipment cost, within the range of accuracy of the estimate | |
| Non-construction implementation considerations | • Additional training requirements, in part due to H&S concerns | • Potential for reduced training requirements |
| Operational considerations | • Highly corrosive chemical (typical PPE to handle HFA: face shield, gloves, coveralls)<br>• Creates a white, chalky powder around the room, and etches glass<br>• Operator interaction required to transfer HFA from the delivery drum to the bulk storage tank | • Regular interaction required to ensure level of NaF in the saturator bed is sufficient<br>• Water softener salt levels need to be checked regularly |
| Maintenance & renewals considerations | • Routine maintenance/ cleaning associated with chemical metering pump system and storage tank<br>• Corrosion of pumps an any co-located equipment (heaters, fans, etc.) reduces asset life<br>• Additional equipment: transfer pump | • Insoluble fractions and hardness residuals require periodic cleanout – mitigated by softening upstream<br>• Additional equipment: water softener and heater |
| Chemical supply | • Opportunity for local supply, as a by-product of local fertiliser manufacturing<br>• Lower chemical cost<br>• Container disposal at a hazardous waste site is required | • Higher chemical cost (approximately 50% chemical cost increase based on use of 5 kg canisters) |

## HFA CONCEPTUAL DESIGN

A general arrangement model was developed to standardize the layout for Christchurch HFA-based fluoridation systems, as shown in Figure 5.

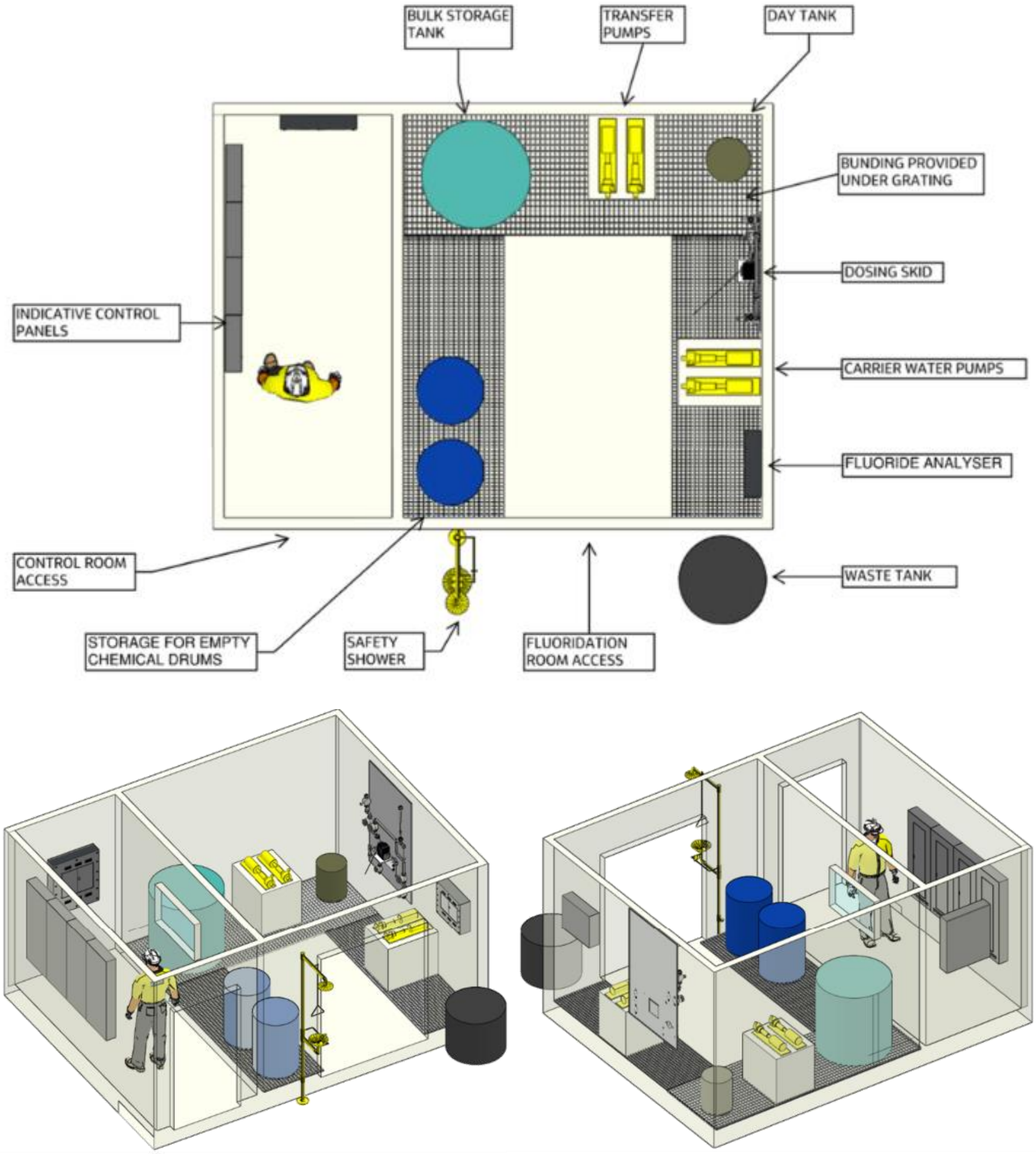


*Figure 5: HFA system general arrangement*

Chemical storage was provided for a minimum of 14 days' operation at average flow and average dose. The conceptual designs call for the construction of a new building or a building footprint expansion to house the fluoridation system. Based on the general arrangement established, a 3.8 m x 5 m footprint was estimated for small and medium-sized facilities if no site-specific customizations are required, and a 3.8 m x 5.3 m footprint for large facilities.

## NaF CONCEPTUAL DESIGN BASIS

The NaF system design was based on delivery of NaF in 5 kg foil-sealed canisters for use with a bottle loader, which employs a retractable blade and auto-rinse functionality to minimize dust creation while transferring chemical to a saturator. It is not anticipated that the used NaF containers would require hazardous waste disposal, unlike HFA. NaF canisters would be unloaded into an upflow saturator to form a bed of solid chemical, resulting in a consistent saturated fluoride solution given NaF's near-constant solubility. Provisions for a softened water supply were included to reduce nuisance scaling and minimize maintenance requirements for the saturator bed. From the saturator, an appropriate daily quantity of fluoride solution would be transferred to a day tank once per 24 hours from where it would then be dosed into the water supply line. A simplified process block diagram of the NaF dosing system is presented in Figure 6.

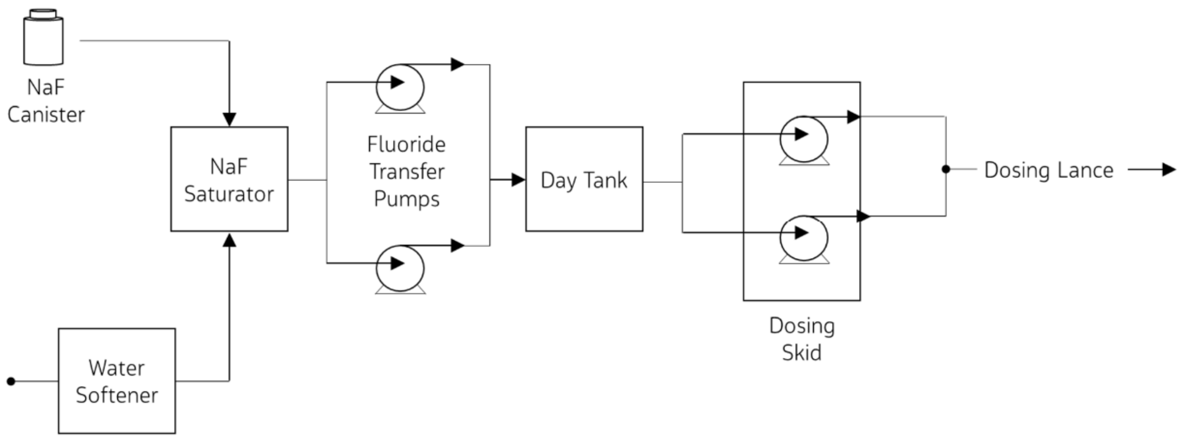


*Figure 6: NaF system block diagram*

A general arrangement model was developed to standardize the layout for Christchurch NaF-based fluoridation systems, as shown in Figure 7; the following considerations and features were incorporated:

- Controls and chemical equipment co-located in one common fluoridation room
- Roll-up door for ease of delivery
- All process equipment and storage tanks located above a bunded area which can be rinsed to a waste holding tank in case of chemical drips from the transfer pumps or dosing skid
- Sunken bunding with a grate overtop at grade to remove the tripping hazard of a bund kerb
- Storage space for NaF canisters for a minimum of 14 days' supply at average flow

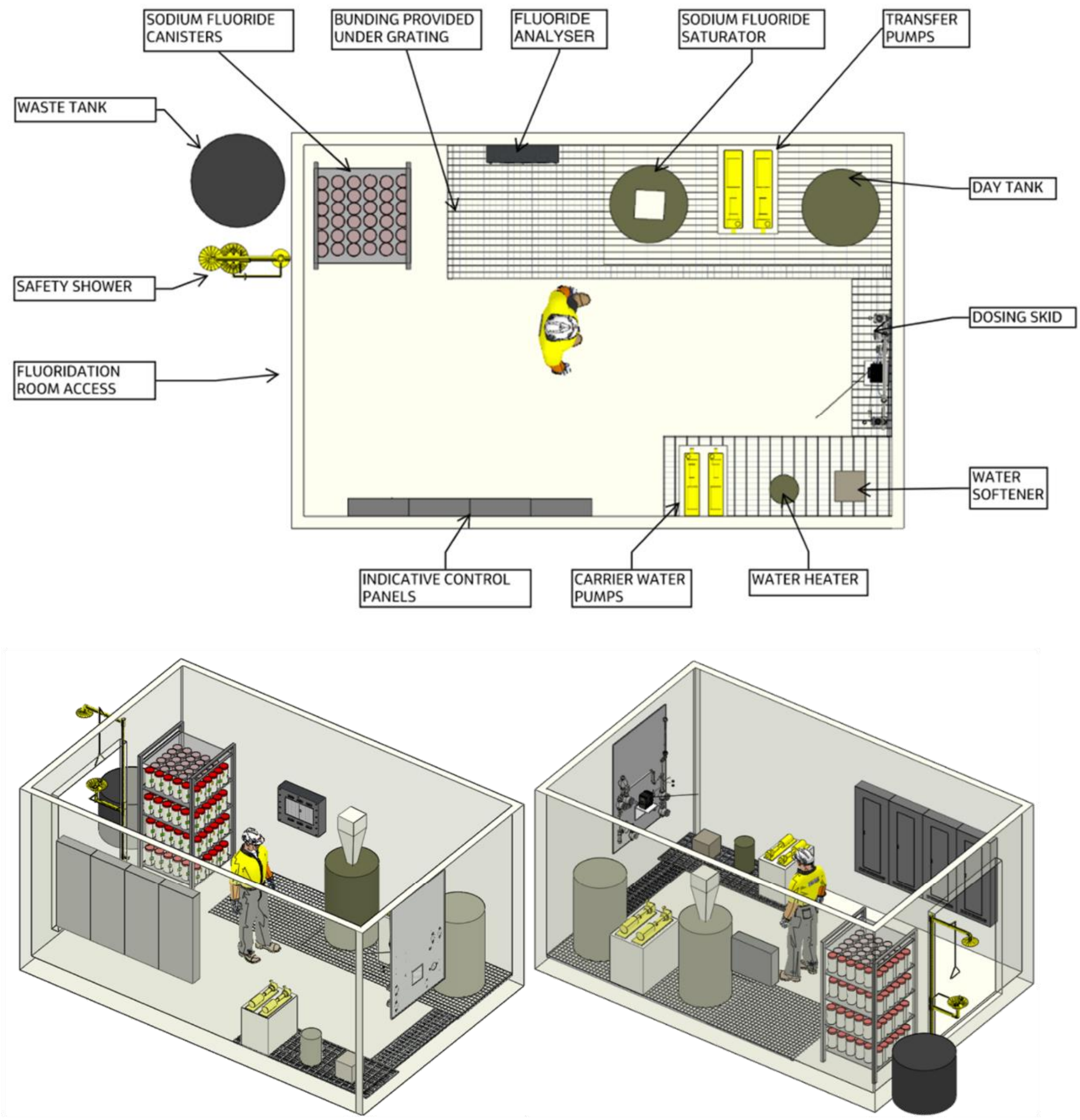


*Figure 7: NaF system general arrangement*

Structural requirements for an NaF-based fluoridation system were similar to the requirements for an HFA system. A 5.1 m x 3.3 m footprint was estimated for medium-sized facilities, with civil requirements for an NaF-based fluoridation system equivalent to those of an HFA system.

## SITE-SPECIFIC LAYOUTS

The five reference facilities for which site-specific layouts were developed were selected to span a range of flowrates and capacities, site constraints, and pumping configurations to provide a representative cross-section of the fluoride implementation considerations. A summary of the selected sites is included in Table 3.

*Table 3: Summary of reference facilities included in Phase 2*

| Site | Configuration | Facility Designation | Future Design Flow ($m^3$/hr) | Current Average Flow ($m^3$/hr) |
|---|---|---|---|---|
| Main Pumps | Suction tank ahead of pumps, pumping directly into mains | Large | 1000 | 450 |
| Grassmere | Suction tank ahead of pumps, pumping directly into mains | Medium | 528 | 234 |
| Redwood | Submersible, pumping directly into mains | Medium | 425 | 142 |
| Tara | Submersible, pumping directly into mains | Small | 120 | 63 |
| Akaroa WTP | Surface water supply with WTP ahead of reservoir | Small | 88 | 45 |

These reference facilities site layouts were used to review and validate assumptions made in the Phase 1 estimates for civil works including delivery vehicle access, pipework alignment and length of trenching required for dosing and analyser sampling lines, and tree removal requirements. These site-specific designs also considered integration with any ongoing or planned capital work, providing an overview of facility master-planning considerations to facilitate the integration of future fluoridation equipment.

**HFA-BASED CAPITAL ESTIMATE UPDATE**

Capital cost estimates for the 5-HFA and 1 NaF-based reference designs were developed, and construction value subtotals were found to vary from the Phase 1 estimates by 4 – 28%, with the higher variance of 28% corresponding to the addition of a new building at a facility where the previous estimate had assumed the fluoridation equipment could be housed within the existing building.

Non-construction costs for Council were estimated on a system-wide basis as part of the Phase 1 efforts. These estimates have not been updated as part of the site-specific reference concept development, as they pertain to costs which are incurred at the system level rather than the individual facility level. These system level costs include CCC internal program management, documentation updates and template development, safety training, engineering, etc.

This conceptual cost estimate was approximately three times the original cost produced in 2017. The primary cause for this increase was a developed understanding of severe site constraints with a lack of existing permanent structures to house equipment. The pump stations are limited regarding space for treatment controls and instrumentation and have varied production capacity. The implementation of fluoridation will require extensive non-construction costs associated with documentation updates, staff training and SCADA upgrades. Inflation and supply chain constraints have also increased dramatically since 2017.

### HFA vs. NaF COST COMPARISON

Capital cost estimated for HFA- and NaF-based systems at the Grassmere facility were within 10% of one another and were therefore not considered significantly different within the accuracy of the estimates.

Chemical costs for NaF were estimated to be 27% higher than those for HFA at the selected medium-sized reference facility, reflective of the 5-kg canister supply which was assumed as the design. Contract management, PO and invoice management, compliance, operating, and maintenance efforts were estimated on a system basis, and thus were not re-evaluated as part of the Phase 2 efforts.

A comparison of renewal estimates for the two alternate designs over a 20-year horizon was completed. The corrosive nature of HFA was reflected in the reduced lifespan for chemical system components and appurtenances (10 years vs. 20 years for an NaF-based system), and the resulting higher annualized renewal cost.

## CONCLUSIONS

Christchurch City Council was able to respond to the Director-General’s request for costs and timeframes to implement fluoridation by the stated deadline, and within 5 weeks of appointing Jacobs. The response to the Director-General confirmed that the accuracy of the cost estimate is considered to be +/- 30%. It was also noted that an implementation delay of at least 24 to 48 months should be provided to enable Council to complete the many safe drinking water improvements projects already underway.

Council was briefed on the implications of fluoridation after the submission of information to the Director-General in March 2022. Council expressed their concerns about funding requirements and the impact of potential funding decisions on the general public (the Act states that a local authority will not be required to consult on any matter related to the direction to add fluoride to the water).

Three Waters Management instructed its Planning and Delivery teams on the 3rd of May 2022, to ensure that designs for new pump stations or significant pump stations upgrades, should make provision for fluoride dosing equipment to be installed in the future. In order to enable a consistent design approach, Jacobs were requested to prepare a fluoridation design considerations checklist.

The Director-General responded to Council's submission on the 17th of June 2022 and advised that the Christchurch City Council will not be included in the first set of potential directions to fluoridate drinking water but stated that a decision would be made by the end of 2022. It was noted that should a direction be made, compliance dates could potentially be set for after July 2024, when the new water service entities are established. In the letter, the Director-General emphasized that the current cost estimate provided by Council was more than three times the 2017 estimate. Given the Phase 2 work, Council can now confirm the Phase 1 cost estimates as valid and relevant.

The Christchurch City Council, with the support of Jacobs, are preparing to present the findings of the concept design and costing to the Ministry of Health.


## ACKNOWLEDGEMENTS

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