INNOVATING EXISTING INFRASTRUCTURE

Nicola Smalberger (Brown), Harrison Grierson Consultants Ltd

ABSTRACT

In many projects completed for smaller rural councils, the budgets are lower and the perceived value of the existing equipment is higher. This means that there is often a driver to re-use existing plant where possible. However, re-furbishing, re-using or replicating existing plant comes with many risks and pitfalls. It is important to identify these risks prior to selecting an item for re-use as rectifying these issues later in the project may lead to unacceptable increased costs. Some of the issues which will be discussed are:

- Compliance with the DWSNZ 2005 (revised 2008)
- Structural integrity of existing structures
- Design constraints when re-using process items
- Design flaws in the existing equipment
- Modifications to existing structures

It is key to understand what is important to the client and ensure this is incorporated throughout the project. This can include identifying opportunities for re-use and potential cost savings throughout the whole project life cycle. It is also important to be able to assess the costs and benefits of re-using certain items vs installing new.

In recent projects undertaken, a great amount of time and analysis has been invested into re-using existing infrastructure in new and innovative ways through re-use, refurbishment and retrofitting. This paper will discuss common reuse upgrades and the issues and advantages associated with these. Additionally the paper will detail a number of recent case studies where innovative optioneering studies and refurbishments have been completed to reduce the overall project cost.

KEYWORDS

Drinking Water, Upgrades, Re-use of Infrastructure, Innovation

1 INTRODUCTION

Almost all upgrade projects involve some refurbishment or retrofitting of existing infrastructure. It’s is less common to have a “green fields” project where the designer is able to use standardized designs for all their process units and structures. There are many opportunities for cost savings arising from the reuse and refurbishment of existing infrastructure, but there are also many traps and pitfalls which can present themselves during the project.

2 ISSUES ASSOCIATED WITH REUSE

Often it has been found that there are a large number of issues which may arise during design and construction when re-using existing infrastructure. These can be anything from design flaws of the original design to in-correct as-built drawings.

Some issues may be risks to the project, these can potentially lead to variations during the construction phase. Care should be taken to address these issues during the design phase so they do not lead to unforeseen costs to the project.

2.1 COMPLIANCE WITH NEW ZEALAND DRINKING WATER STANDARDS

The first issue which always needs to be addressed when looking at re-use of existing infrastructure is compliance with the New Zealand Drinking Water Standards (DWSNZ 2005 revised 2008). Does the process item have the facility to meet with the requirements of the New Zealand Drinking Water Standards? The process item may require significant modifications to meet with the requirements of the standards, such as installing filter-to-waste facilities for filter upgrades. Care should be taken to assess the process items capability to meet with compliance requirements prior to selecting an item for re-use.

2.2 STRUCTURAL INTEGRITY

As water treatment plants are considered to be critical infrastructure, the Council will most likely have a requirement for the structural integrity of the plant. This issue will become more and more prevalent after the events in Christchurch, which showed how vulnerable water supply infrastructure can be around New Zealand. Generally, council's will require existing infrastructure to be re-used to meet a certain percentage of the New Building Standard (NBS). If the infrastructure does not meet this requirement, costly strengthening exercises may be required.

2.3 DESIGN CONSTRAINS WITH REUSE

When re-using existing infrastructure, the unit may not be able to be designed as per "best practice". This is because the design has to work around the current installation as best it can. When designing a bespoke process unit, the design will be able to be fairly standardized and as per industry best practice. When designing a refurbishment the design may need to be modified to fit the application. This means that design flaws may be inadvertently created in what would normally be a standard installation.

2.4 DESIGN FLAWS OF EXISTING EQUIPMENT

Any design flaws present with the unit in question will be transferred to the upgraded plant if these flaws are not identified and rectified in design. This issue is also prevalent in upgrades where existing process units are replicated to increase the plant capacity. If the existing plant is inappropriate or inadequate in some way this issue will be transferred to the new plant potentially producing undesirable outcomes.

The design must allow for working around all existing fixtures and care should be taken to assess each part of the process unit individually rather than modifying an existing design. Additionally, it is often useful to have early engagement of the operators of the existing plant. They may be able to highlight issues with the existing plant which may not have come to light until late in the design process or even during construction or commissioning. This can save time on costly re-design and construction variation.

2.5 MODIFYING EXISTING STRUCTURES

Another issue which must be addressed when looking at re-use and refurbishment projects is the risk of uncovering unknowns during construction. This is often the result of incorrect As-Builts or ad-hoc modifications which have been completed between plant upgrades. There is often no way to identify these issues prior to the construction phase unless there is an operator or engineer who has been involved in one plant for a very long time. As there is no way to avoid unknowns as they are just that "unknown", it is important to allow an appropriate amount of risk money and buffer in the program for dealing with these issues as they arise.

3 ASSESSING EXISTING STRUCTURES

3.1 DEFINING "CRITICAL INFRASTRUCTURE"

Understanding which items are considered to be "critical infrastructure" is a key part of assessing existing structures. Items which are required for the plant to be able to meet production and comply with the New

Zealand Drinking Water Standards will be considered critical infrastructure. Items which are not part of the main process stream may not be considered critical infrastructure. Examples of this may be sludge holding tanks, raw water storage tanks, operator's areas (i.e. lab and office) and non-critical chemical dosing (i.e. pH adjustment).

3.2 COMPLETING ASSESSMENTS

An important part of completing an assessment is the timing of the assessment. Structural assessments can be a costly exercise, which would be wasted if the item ends up not being used in the final design. Generally, it is advisable to wait until an option is selected in concept design, and then complete the assessment during preliminary design stage. This means that the item has definitely been selected for use before the assessment but the assessment will not require **too** much re-work if the item is found to be unviable for re-use. Leaving assessments any later in the project puts an unnecessarily high risk on the project outcomes.

As-built structural drawings of the item will be required for the assessment. However, often for older plants, As-Builts may be not up to date, hard to obtain or not available at all. If the original structural As-Builts are not available, core sampling may be required to ascertain the amount and condition of the concrete and reinforcing. Care must be taken to include the proposed modifications to the building in the assessment. Often as part of an upgrade existing items will be removed and new doors, windows, tanks and heavy machinery will be installed. This can all affect the outcome of the assessment.

If the structure is found to be in poor condition and does not meet the required percentage of the new building standards the value of the item may be significantly less than what the Council has on its books. This may mean that other options which were previously more expensive become viable if they rely less heavily on existing infrastructure. Options can be looked at to replace or strengthen the item which may affect the outcome of the project.

3.3 EXISTING RISING/FALLING MAINS

Assessing the condition of existing rising and falling mains can be difficult as these often cover significant distances, are buried and often cross land not owned by Council. A main burst can be a significant problem for Councils and can lead to failure to meet production for the area.

Considering that the cost of replacing an entire rising or falling main can be a significant proportion of the capital cost for the project, there is real value in re-using pipework where possible. This is particularly true for raw water mains which often bring water from sources many kilometers away.

Even more than with process units, it is important to identify risks associated with the rising and falling mains to and from the plant early in the design process. Identifying areas which may be at risk due to pipe material degrading, hydraulic loading or even landslides is important.

4 COMMON REUSE UPGRADES

The most common upgrades which are undertaken by councils are most obviously upgrades to meet the New Zealand Drinking Water Standards and upgrades to increase the existing plant capacity. For both of these types of upgrades there are a number of items which are commonly completed to achieve these two objectives.

4.1 INCREASING FLOCCULATION TIME

Commonly, when the capacity of the plant increases, the volume of the flocculation chamber(s) will no longer be adequate due to the increased flow. Additionally, the original plant may have insufficient flocculation time and the clarifiers (or filters with direct filtration) may be running at less than optimal performance. Generally the easiest way to increase the flocculation time is to install another chamber, upstream of the existing. In this case the existing flocculation chamber can be re-used as with minor modifications. Mechanical mixing may be required to be retrofitted into the existing chamber.

An example of this type of upgrade was completed at Ngaruawahia WTP where a second freestanding chamber was installed adjacent to the existing chamber to double the flocculation capacity. This allowed the required capacity increase for the plant and improved the flocculation conditions for the two blanket clarifiers.

4.2 RETROFITTING CLARIFIERS

Increasing the throughput of an existing clarifier is often a requirement of an upgrade project. Clarifiers can have a significant structural value as they are generally the largest process item on the site. As such it is important to make use of this item the best way possible. As there are many different types of clarifiers installed at plants around the country it is difficult to generalize on this topic. However, the majority of plants dealt with have either radial flow sedimentation clarifiers or up flow blanket clarifiers.

A highly effective way of increasing the through put of an up-flow blanket clarifier is to convert it to a horizontal flow tube settler clarifier. This can increase the rise rate from 1.5 – 2 m/hr to 5 – 15 m/hr, more than doubling the production of the clarifier for the same area. Challenges in completing this type of upgrade are:

- Effective sludge removal, usually requiring the installation of a sludge scraper system.
- Achieving appropriate length to width ratios which will depend on the arrangement on the existing clarifier.
- Maintaining clarified water flow to the filters while the clarifier is out-of-service for refurbishment. This can severely restrict the plant flow and must often be completed over the winter months. This issue can be a particular problem if there is only one clarifier onsite.

This type of upgrade was completed successfully at Ruakaka WTP and Kerepehi WTP which are discussed in section 7.1 below.

Radial flow clarifiers can also be converted in this manner, with the inlet in the centre of the tank and tubes arranged in a circular pattern with flow from the centre outwards

4.3 FILTER AUTOMATION

A common upgrade which is completed by many Councils is the automation of the existing filters. This is required to meet with the current New Zealand Drinking Water Standards. Automated filter backwash is required to ensure the filter is not producing water above the requirements of the standards. Installation of filter-to-waste is also required to ensure that “off-spec” water which is produced when a filter is brought back online after a backwash is not sent to supply.

Some of the issues which can be encountered when completing a filter automation upgrade are as follows:

- Space restrictions for new pipework and actuators as these generally take up more space than the existing manual valves.
- Increased backwash rates leading to larger diameter pipework being installed.
- Pipe lengths required for Magflow meter installation to produce accurate readings. The requirements of the manufacturer can often be difficult to achieve in restricted installations.
- Maintaining filtered water flow from the plant while filters are out-of-service for refurbishment. This can severely restrict the plant flow and must often be completed over the winter months.
- Length of time required for the upgrade as generally filters must be upgraded one at a time rather than all at once.

4.4 FILTER FLOOR REPLACEMENT

It has been found on previous projects that if the filter floors require replacement and the filter requires automation that it is similar order costs to install new bespoke or package filters than to upgrade the existing.

This can often be difficult for Council's to justify as the filter is seen as having significant value. If other innovative ways of reusing the existing filter shells can be found this may help with this issue.

5 OPTIONEERING STUDIES

A number of optioneering studies have been competed on recent projects to look at the cost effectiveness of innovative ways of re-using different plant items. This kind of options assessment can significantly reduce the overall capital cost of the project. A few of these are detailed below.

5.1 KEREPEHI WTP – PARALLEL STREAM ASSESSMENT

As part of the concept options assessment for the recent Kerepehi WTP upgrade the options of maintaining the existing process stream were considered. The basis of these options were to maintain the process stream of the existing plant which would produce 6.25 Mld and install a new parallel plant which would produce an additional 6.25 Mld to bring the total plant capacity up to 12.5 Mld. The two streams would be kept completely separate until they discharged into the reservoir. It was found that to completely re-use the existing process stream and to install a new parallel was only 7% – 10% less than the cost of installing a completely new plant. This did not include any modifications to the existing plant but did maximize the possible reuse of the existing infrastructure.

In the end, the decision was made to go for a full plant upgrade rather than to install a side stream plant due to the fact that the compliance for the plant would be dependent on the performance of the existing plant. Additionally, having essentially two separate plants would complicate controls, maintenance and operations.

5.2 KEREPEHI WTP – CHLORINE ROOM ASSESSMENT

During detailed design for Kerepehi WTP a number of different locations and arrangements of the chlorine room were looked into. A second chlorine drum was required for the upgrade and as such the chlorine store required a larger footprint. The options looked at were as follows:

a) Modifying the structure of the existing room to create more space for a second chlorine drum, re-locating the existing gantry and modifying the existing bi-fold doors.

b) Building a new chlorine store inside the existing building, installing a new gantry to lift the drums into place and modifying the existing access door to be bi-fold around the gantry.

c) Building a completely new chlorine store outside the existing building which could be a standard chlorine store design.

After cost analysis it was found that building a new chlorine store inside the existing building was the most cost effective option. This option provided the best of both worlds as it required no structural modification to the existing building but maximized the re-use of existing spaces. Some of the issues which had to be addressed in the design of this chlorine store were;

- Chlorine drum delivery – how to most easily get the chlorine drums into place.

- Chlorine standard – ensuring the new installation complied with the chlorine standard in terms of access requirement

- Chlorine gas leak detection – ensuring all floor drains and vents were dealt with appropriately.

- Chlorine monorail – ensuring enough height to lift one drum over the other without significant structural modifications to the building and existing doorway.

5.3 PAEROA WTP – MEMBRANE PLANT LOCATION

For the Paeroa WTP upgrade, the proposed design is to install a membrane filtration plant to provide 4 log credits for protozoa. A number of arrangements of the membrane plant with varying degrees of reuse were considered in the preliminary design. The options were as follows:

a) Construct a new bespoke building to house the membrane plant, reuse the existing filters as a membrane feed tank.

b) Decommission the existing filters, split them in two and line them with a protective coating. Install the filter modules inside the concrete shells of the filters. A new raised membrane feed tank is required for this option.

c) Decommission the existing filters entirely and construct a roof overhead to create a new plant room. Install the membrane cells inside the filters with access from the filter gallery. A new raised membrane feed tank is required for this option.

d) Raise the roof of the existing building and install the membrane plant inside the building. A new raised membrane feed tank is required for this option.

e) Lower the floor of the existing building and install the membrane plant inside the building. Reuse the existing filters as a membrane feed tank.

The lowest cost and most advantageous option was found to be option D, raising the roof of the existing building. This option has been selected for detailed design. There are many issues which are being address in this arrangement, the most pressing of which is space for the membrane plant. Other issues include hydraulic profile, location of sludge disposal, jacking of the roof and locations of ancillaries which will be fitted inside the plant.

6 CHEMICAL AREAS

The most common method of re-using existing buildings is to re-fit them with the new chemical installations. This can often be challenging as the chemicals are often required to fit into quite tight spaces and issues such as chemical delivery, bunding and compliance with hazardous standards must be addressed. Additionally if the plant has had a capacity increase the installations often require increased space for storage.

6.1 SEPARATING STORAGE FROM DOSING

One way of creating additional space in the chemical store is to move the chemical tanks outside and have only the chemical dosing bunds inside the chemical store. This means that less space in the store is taken up by large storage vessels. Caution needs to be taken with separation distances between tanks and pumps as chemical pumps do not always have a lot of suction lift. Additionally, having uncovered bunds outdoors can lead to issues with rainwater and drainage which complicates the actual bund storage capacity and leak detection.

6.2 CREATING FALSE BUNDS

If the chemicals are being delivered in drums or IBC's, instead of having a bund wall upstanding in the middle of the room which the drum needs to be lifted over, an alternative is to raise the floor level in the whole chemical store leaving recesses for chemical bunds. Grating is then installed over the chemical bunds at the same height as the new floor level. The drum or IBC can be maneuvered into the bund using a trolley or pallet jack.

6.3 DOUBLE SKINNED TANKS

Another way of creating more space in a chemical area is to store chemicals in double skinned tanks. This reduces the amount of space required for the bund which would normally be constructed around the tank. The designer should be careful to ensure the chemical pump has enough suction lift to draw the chemical out of the tank as these tanks are top exit.

7 EXAMPLES OF REUSE

A number of successful process items have been re-used in recent projects, the design factors, issues and successes are discussed below.

7.1 KEREPEHI FILTERS

The existing filters at Kerepehi were considered for refurbishment as part of the upgrade, however as they did not have the required capacity for the upgrade and required significant refurbishment to comply with the standards they were discounted. However, this did provide the opportunity to re-use them as membrane feed tanks. The filters we ideal for this purpose for the following reasons:

- They were already connected to the outlet of the clarifiers.
- They provided adequate hydraulic head to drive water though the pre-membrane screens.
- They provided adequate volume to re-fill the membrane cells quickly after a backwash.
- They already had level sensors installed which could be reused in the upgrade

The issues which had to be overcome when re-using these filters in the design were:

- The water-tightness of the filter shells was in question (this was found to not be an issue)
- The filters operated together which provided difficultly when taking one out of service for tie-ins.

In practice the filters work well as membrane feed tanks and required little modification to achieve the required functionality.

7.2 RUAKAKA FILTERS

At Ruakaka, there were two existing filters that required refurbishment, including new pipework and new filter floors as part of the overall plant upgrade. It was found that building 3 new filters had the same cost as stripping the 2 existing filters and refurbishing them. As such, three new filters were built. This highlights the fact that in many older plants, the remaining value in the plant is only the structure left over after the process and mechanical items are removed.

7.3 RUAKAKA AND KEREPEHI CLARIFIERS

The existing clarifiers at Ruakaka were modified from up-flow blanket clarifiers to horizontal flow tube settler clarifiers. A similar upgrade was completed on the Kerepehi clarifiers in the recent upgrade. In both cases, converting the clarifiers to tube settlers increased the rise rate from 1.5 – 2 m/hr to over 5 m/hr, more than doubling their capacity. This meant that the design required no new clarifier to be constructed.

The existing clarifiers were ideal for this purpose for the following reasons:

- Their area was large enough to provide the required clarified water flow for the upgrade.
- They were deep enough to provide space for launders, tubes and sludge scraper with adequate separation distances.
- Their length to width ratios were appropriate for tube settler clarifiers.

Modifications to the clarifiers were as follows:

- Installation of new flash mixer and flocculation towers upstream.
- Installation of a new raw water inlet to the clarifiers.

- Installation of a new baffle plate at the inlet end of the clarifier.
- Installation of a new sludge disposal mechanism at the bottom of the clarifier.
- Installation of new launders for collection of clarified water.

A few issues encountered in these installations which had to be resolved. At Ruakaka, the sludge disposal was at the opposite end to the raw water inlet which is less advantageous for effective solids removal. At Kerepehi the drawings of the clarifiers were inaccurate leading to difficulty during installation. Both these issues were resolved and the clarifiers now work optimally, producing clarified water consistently less that 1 NTU.

7.4 KEREPEHI RAW WATER STORAGE TANK

At Kerepehi, the plant suffers from high turbidity events which occur during king tides in the Firth of Thames. The reuse of the raw water storage tank aided the plant in buffering out the peak turbidities which occur for short periods at high tide. This item was assessed structurally at a high level and the decision was made to re-use the tank as is and replace it at the end of its life cycle. This is possible as the tank has a bypass line which allows the plant to run without the use of the tank.

The re-use of this tank has been discussed in detail in a previous paper "King Tides – A Royal Problem".

7.5 NGARUAWAHIA CLARIFIED WATER PUMPS

As part of the upgrade to the Ngaruawahia WTP, a capacity increase was required. The clarified water pumps did not have the required capacity to meet the increased flow. However after investigation it was found that the existing pumps could be re-used if a larger motor was installed. This meant that the capacity of the pumps could be increased without having to modify any of the existing pipework around the pumps.

7.6 NGARUAWAHIA FILTERS

The filters at the Ngaruawahia WTP were refurbished for automation and to comply with the New Zealand Drinking Water Standards. It was more advantageous to upgrade the existing filters at Ngaruawahia as there was little space onsite to install new filters and the filters had high value.

Modifications to the filters were as follows:

- Raw water, filtered water, backwash water pipework replacement.
- Installation of automated valves for raw water, filtered water, backwash water.
- Installation of a new filter-to-waste capability.
- Installation of a new raw water inlet chamber to the filters to balance the flow.
- Replacement of the filter floors.
- Installation of a new backwash water discharge facility.

Some of the issues which were encountered during design of this refurbishment are as follows:

- Operation of the filters was complicated during the upgrade as some filters were operating on the new control system and some on the existing control system.
- Space was very restricted in the filter gallery, as a lot of design work was put into finding innovative ways of fitting new pipework and valves in the existing space.
- Late in the design phase an issue was raised by the operators that the washout bay did not discharge wash water quickly enough and this would cause an overflow of dirty water onto the second filter bed. Some re-design work was required late in the design process to address this issue.

The arrangement of the plant is such that the clarified water is pumped to the filtration plant which is uphill. It is believed that this causes the floc to be broken up making it more difficult for the filters to achieve below 0.1 NTU. As the raw water is assessed to require 4 log protozoa removal, the filters must achieve 0.1 NTU increasing the filter-to-waste times and waste discharge volumes.

8 SUMMARY

In summary, it has been found that completing optioneering studies on the reuse, retrofitting and refurbishing of existing infrastructure can improve the outcome of the project by:

- maximizing the reuse of existing infrastructure to reduce overall project costs;
- ascertaining the true value of existing infrastructure;
- assessing the costs and benefits of re-using certain items vs installing new; and
- ensuring the Council is getting the best value for money from their project.

Issues which need to be carefully considered when looking at the re-use of existing infrastructure include:

- required modifications to achieve compliance with the New Zealand Drinking Water Standards;
- structural integrity of the item in question;
- design constraints of the item which will prevent “best practice” design;
- existing design flaws already associated with the item;
- innovative re-use which can repurpose an item for a completely different use; and
- innovative arrangements which can save space and maximize the use of existing buildings.